Washington State Department of Transportation

US 101 MP 268.54 Discovery Creek (991667): Preliminary Hydraulic Design Report Supplement

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US 101 MP 268.54 Discovery Creek
Preliminary Hydraulic Design Report Supplement
May 2021

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Contents

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1 Introduction and Purpose

This Preliminary Hydraulic Design (PHD) supplement provides an addendum to the PHD authored in September of 2020 by WSDOT staff. Background information that was gathered from the site visit and other hydrologic information that was used for development of the SMS-hydraulic model was not changed for this analysis. After the Draft PHD, this crossing was advanced to a concept level design with updates to provide additional bench width for wildlife connectivity, add channel sinuosity through the crossing to more closely mimic the upstream reference reach planform, and shift the stream alignment to avoid the potential for a large retaining wall near the Sequim Bay Lodge. The intent of this supplement is to document these changes to the proposed design since the PHD, to update the hydraulic model, and concisely report results. The information contained in this supplement supersedes that of the September 2020 PHD. The proposed project will replace the existing culverts with a minimum 23-foot-wide hydraulic opening which includes a 13-foot-wide bankfull width channel section and 5-foot benches on both sides for wildlife connectivity. For additional information refer to the September 2020 PHD.

2 Site Assessment

See **Appendix A** for September 2020 PHD. The site was revisited with representatives from WDFW, Jamestown Tribe, WSDOT, and Parametrix on March 13, 2020 and the bankfull width was agreed to be revised to 13 feet which was the bankfull used for design purposes.

3 Watershed Assessment

See **Appendix A** for September 2020 PHD.

4 Fish Resources and Site Habitat Assessment

See **Appendix A** for September 2020 PHD.

5 Reference Reach Selection

See **Appendix A** for September 2020 PHD.

6 Hydrology and Peak Flow Estimates

See **Appendix A** for September 2020 PHD.

7 Hydraulic Analysis

The September 2020 proposed channel geography was a straight channel which replaced the existing culvert alignment. The revised proposed conditions model improves the channel geography with sinuosity that starts upstream of the existing culvert and continues through the US 101 crossing. The changes to the proposed stream design will add more channel complexity. The stream alignment moved east away from the existing Sequim Bay lodge structure. The proposed step pool configuration has not been re-evaluated with the new alignment. Revised stream design plan and detail sheets are provided in **Appendix D**.

The hydraulic analysis of the proposed US 101 UNT crossing was performed using the United States Bureau of Reclamation's (USBR) SRH-2D Version 3.2.4 computer program, a two-dimensional (2D) hydraulic and sediment transport numerical model (USBR 2019). Pre- and post-processing was completed using SMS version 13.0.12 (Aqueveo 2020). Hydraulic analysis was only evaluated for one scenario; the proposed stream design with a 23-foot structure. The hydraulic analysis of the existing conditions model is documented in the September 2020 PHD and was not re-evaluated for the PHD supplement.

7.1 Model Development

7.1.1 *Topography*

The proposed channel geometry data in the model was obtained from the MicroStation and InRoads files supplied by Parametrix. Survey data collected during the PHD was supplemented by Parametrix with additional topographic field survey from February 2020. All survey information is referenced against the NAVD 88 vertical datum.

7.1.2 *Model Extent and Computational Mesh*

The hydraulic model upstream and downstream extents start and end with survey data that was collected prior to the development of the PHD supplement. The detailed survey data extends approximately 425 feet upstream and 430 feet downstream of the proposed structure. Additional LiDAR data was not stitched into survey surface. Model results showed that there was no noticeable backwatering in the upstream channel that would have required additional surface information. The proposed computational mesh is a combination of patched (quadrilateral) and paved (triangular) elements, with a finer resolution in the channel and larger elements in the floodplain. The proposed condition mesh was created using roughly the same outline from the original PHD existing conditions mesh. The proposed mesh created for this hydraulic design supplement supersedes all proposed hydraulic results. The proposed conditions mesh covers an area of 80,482 square feet (SF). There are 3,918 triangular and 23,700 quadrilateral elements (see Figure 1).

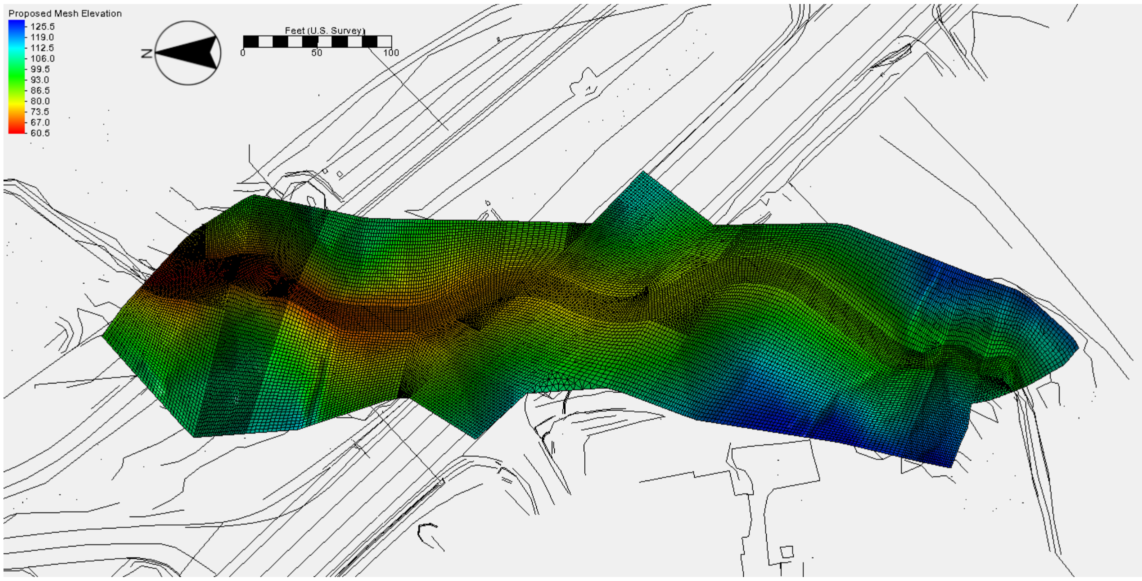

Figure 1: Proposed-conditions computational mesh

Model simulations were performed using constant discharges ranging from 2-year, 100-year, 500-year, and 2040 project peak flow events that were developed in the original preliminary hydraulic design. The proposed boundary conditions (BC) inflow and outflow lines are shown in Figure 1. The BC lines are drawn the same length and same location as in the existing hydraulic conditions model. A constant flow rate was specified at the upstream BC, while a normal depth rating curve was specified at the downstream boundary. The downstream normal depth rating curve was developed within SMS using the surveyed terrain, and an assumed downstream slope of 0.0557 feet/feet that closely mimics the natural streambed, and a composite roughness of 0.06. A slip boundary condition was not applied to the structure abutments because in none of the flow conditions did the wetted area approach the structure abutments. The model simulations were run for a long enough duration for results to be stable across the entire model domain.

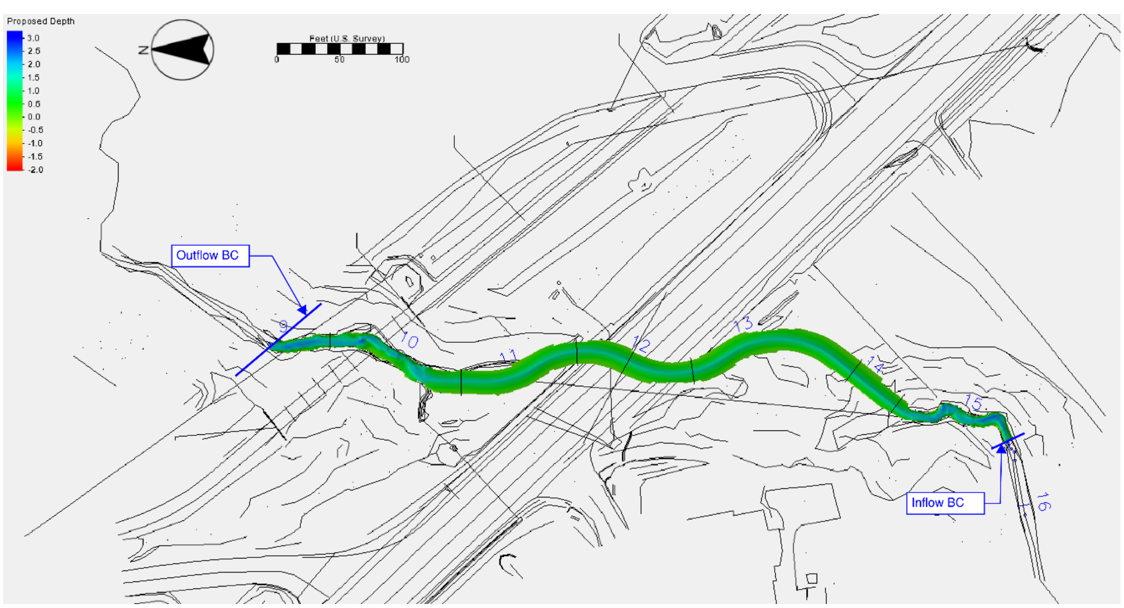

Figure 2: Proposed-condition boundaries

7.1.3 ***Materials/Roughness***

Manning's n values were estimated based on site observations from the September 2020 hydraulic design and are summarized in Table 1. The roughness values upstream in the existing channel grading were increased from 0.05 to 0.06 to resolve an instability in the model which was manifesting as a large reach of supercritical flow. Multiple sensitivity analysis runs with different channel roughness's were conducted to evaluate the instability. Initially, the upstream mesh was changed from triangular elements to quadrilateral with no resulting change to the stability. (Figure **2**).

Table 1: Manning's n hydraulic roughness coefficient values used in the SRH-2D model

Land cover type	Manning's n
Channel	0.06
Existing Channel	0.05
Roadway	0.025
Overbank	0.07

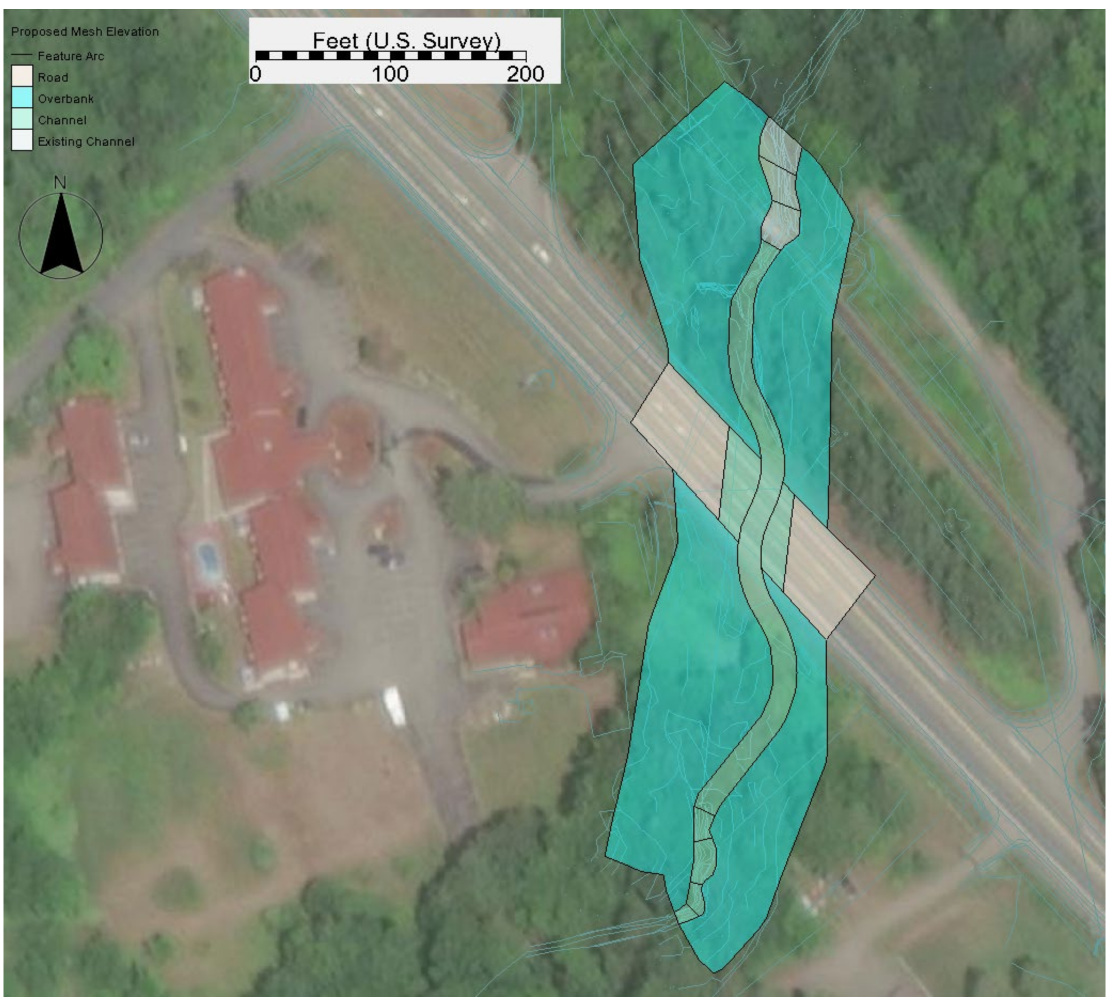

Figure 3: Spatial distribution of proposed roughness values in SRH-2D model

7.1.4 *Model Run Controls*

All simulations were run using the same model controls. Model control variables were adjusted for model stability and adequate runtime to reach a steady state. The following controls were set:

- **Start time:** 0 hours
- **Time step:** 0.5 hours
- **End time:** 4 hours
- **Initial condition:** Downstream boundary condition water surface elevation

7.2 Model Results

The hydraulic opening is defined as the width perpendicular to the channel beneath the proposed structure that is necessary to convey the design flow and allow for natural geomorphic processes. The hydraulic opening assumes vertical walls at the edge of the minimum hydraulic opening width unless otherwise specified. The existing channel is confined and at a significantly lower elevation than the existing US 101 road surface. Future conditions modeling illustrated that removing the existing culvert will not change the confined nature of the crossing. Velocity ratios were calculated using the average upstream channel velocity across the three upstream cross sections compared to the channel velocity through the center of the proposed structure. The velocity ratio was determined to be 1.0 for the 100-year and 2040 projected flows, indicating that there is no increase through the structure. Between the two simulations there was a 0.3 ft/s increase from the 100-year to 2040-year average channel velocities. Velocity ratio calculations are summarized in Table 2.

Table 2: 100-Year and 2040 100-Year velocity comparison

Location	100-Year Velocity (ft/s)	Projected 100-Year Velocity (ft/s)	500-year	Difference (ft/s)	
				100-year	500-year
Average DS of structure	5.3	5.6	5.9	0.3	0.6
Average US of structure	5.4	5.8	6.8	0.4	1.4
Through structure (11+97)	5.6	5.9	6.1	0.3	0.5
Immediately Upstream of Structure (12+49)	5.5	5.8	6	0.3	0.5
Velocity ratio	1.0	1.0	0.9	-	-

Note: Velocity ratio calculated as proposed Vstructure/Vupstream(avg).
Average calculated using velocities from stations 13+89, 14+33, and 15+00

Figure 4 shows the cross sections used to extract and analyze results for the proposed conditions. Cross sections were chosen in both existing grade and proposed channel grading. Table 3 summarizes the main channel and overbank average 100-year velocities for each of the cross sections. The average main channel hydraulic results are summarized in Table 4. The results show that the velocities and shear stresses are similar between the upstream cross sections and downstream cross sections. There is a slight increase in the results beginning at the first cross section of the proposed grading. In the proposed grading the max depth varies by approximately 0.1 feet across all the flow conditions. The proposed water surface elevation profile is shown in Figure 5. The water surface elevations for proposed cross sections are shown in; Figure 6, Figure 7, and Figure 8. The velocity maps for the proposed 100-year and 2040 projected flows can be seen in Figure 9 and Figure 10.

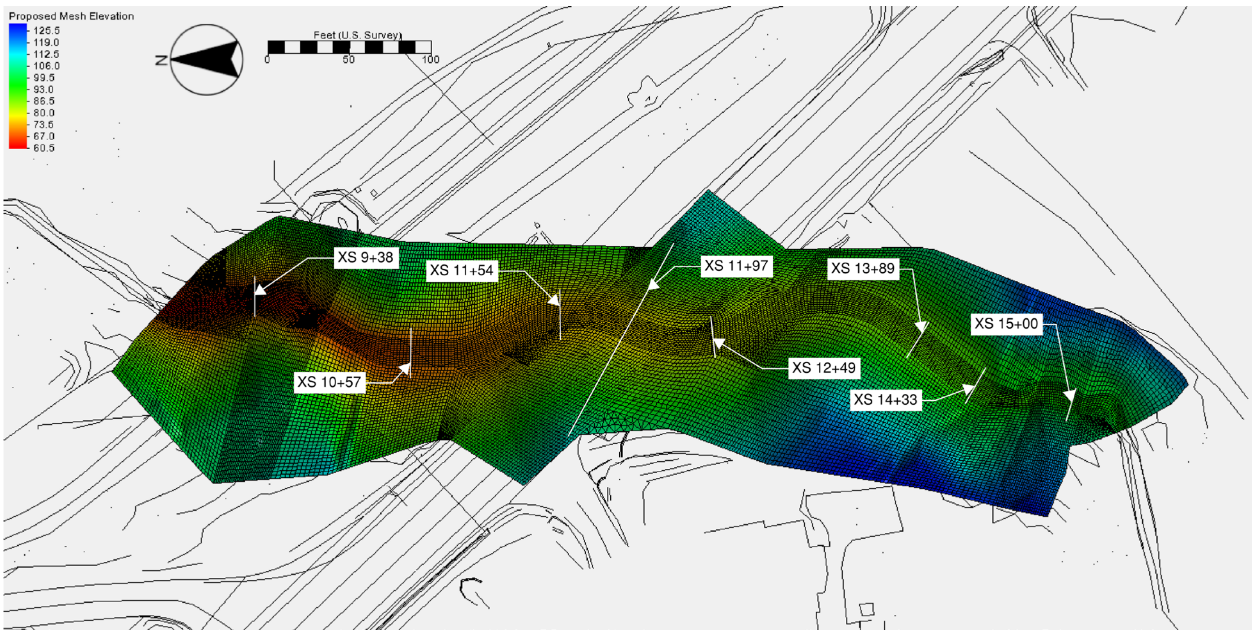

Figure 4: Proposed-conditions mesh with locations of cross sections used for results reporting

Table 3: Proposed average velocities at select cross sections

Location	Q100 Average Velocities (ft/s)		
	Left Overbank[a]	Main Ch.	Right Overbank[a]
Downstream Existing grade (9+38)	3.1	5.5	2.9
Downstream of structure (10+57)	2.0	5.7	2.9
Immediately downstream of structure (11+54)	2.5	5.7	2.8
Through structure (11+97)	2.4	5.9	3.0

Location	Q100 Average Velocities (ft/s) (Continued)		
	Left Overbank[a]	Main Ch.	Right Overbank[a]
Immediately upstream of structure (12+49)	2.7	5.8	2.5
Upstream of structure (13+89)	2.8	5.8	1.8
Upstream of structure (14+33)	3.7	6.5	2.8
Upstream Existing grade (15+00)	0.6	5.1	3.7

a. ROB/LOB locations determined from proposed-conditions 2-year event.

Table 4: Average main channel hydraulic results for proposed condition upstream and downstream of structure

Hydraulic Parameter	Cross Section	2-year	100-year	2040 100-year Climate	500-year
Average water surface elevation (ft)	XS 9+38	63.0	63.8	63.9	64.0
	XS 10+57	68.6	69.1	69.2	69.3
	XS 11+54	74.0	74.6	74.7	74.7
	XS 11+97 (Structure)	76.4	76.9	77.0	77.1
	XS 12+49	79.4	79.9	80.0	80.1
	XS 13+89	87.3	87.8	87.9	88.0
	XS 14+33	89.7	90.3	90.3	90.4
	XS 15+00	93.7	94.4	94.5	94.6
Max depth (ft)	XS 9+38	1.0	1.8	1.9	2.0
	XS 10+57	1.0	1.5	1.6	1.6
	XS 11+54	0.9	1.5	1.5	1.6
	XS 11+97 (Structure)	0.9	1.4	1.5	1.6
	XS 12+49	0.9	1.5	1.6	1.6
	XS 13+89	1.0	1.5	1.6	1.6
	XS 14+33	1.0	1.5	1.5	1.6
	XS 15+00	1.1	1.9	2.0	2.1

Hydraulic Parameter (continued)	Cross Section	2-year	100-year	2040 100-year Climate	500-year
Average velocity (ft/s)	XS 9+38	3.3	5.2	5.5	5.7
	XS 10+57	3.1	5.5	5.7	6.0
	XS 11+54	3.0	5.4	5.7	6.0
	XS 11+97 (Structure)	3.3	5.6	5.9	6.1
	XS 12+49	3.1	5.5	5.8	6.0
	XS 13+89	3.3	5.5	5.8	6.1
	XS 14+33	3.3	6.1	6.5	6.8
	XS 15+00	2.4	4.6	5.1	5.3
Average shear (lb/ft^2)	XS 9+38	1.0	1.7	1.8	2.0
	XS 10+57	1.5	3.1	3.4	3.6
	XS 11+54	1.4	3.1	3.3	3.5
	XS 11+97 (Structure)	1.6	3.3	3.5	3.7
	XS 12+49	1.5	3.2	3.4	3.6
	XS 13+89	1.6	3.2	3.4	3.7
	XS 14+33	1.7	3.9	4.3	4.7
	XS 15+00	0.8	2.4	2.7	2.9

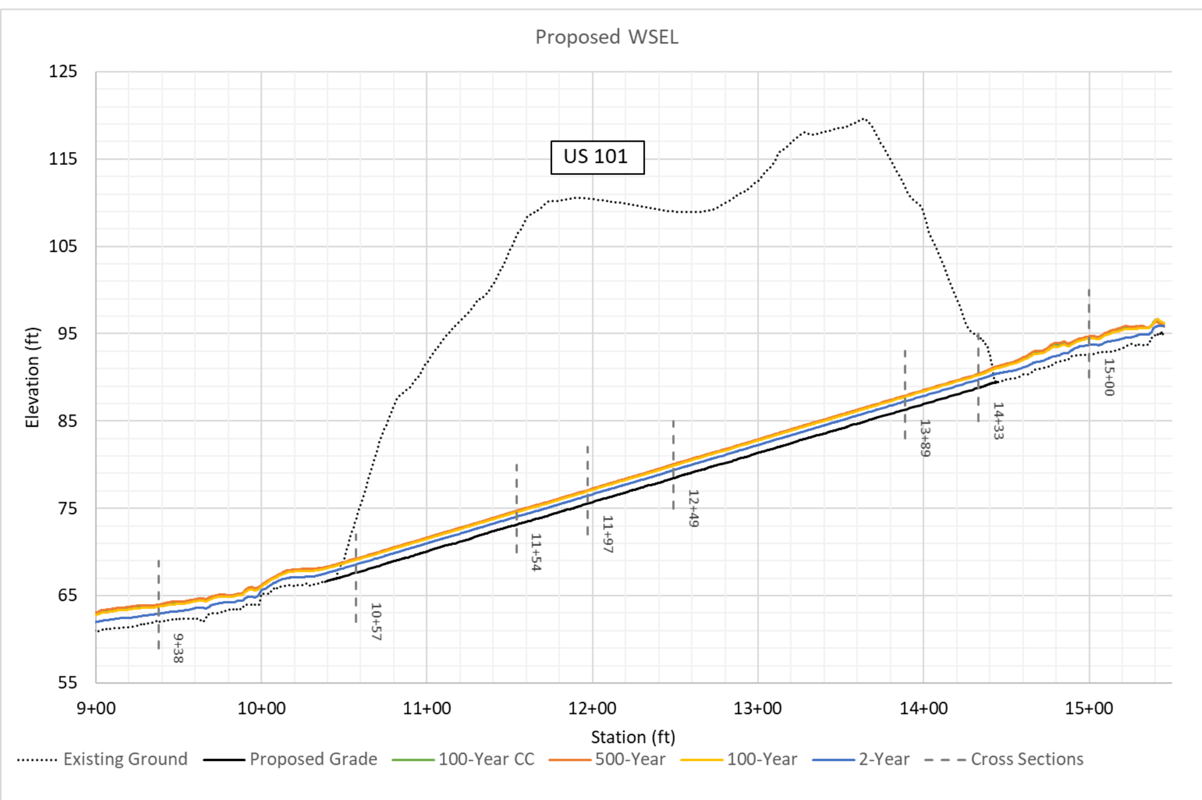

Figure 5: Proposed-conditions water surface profiles

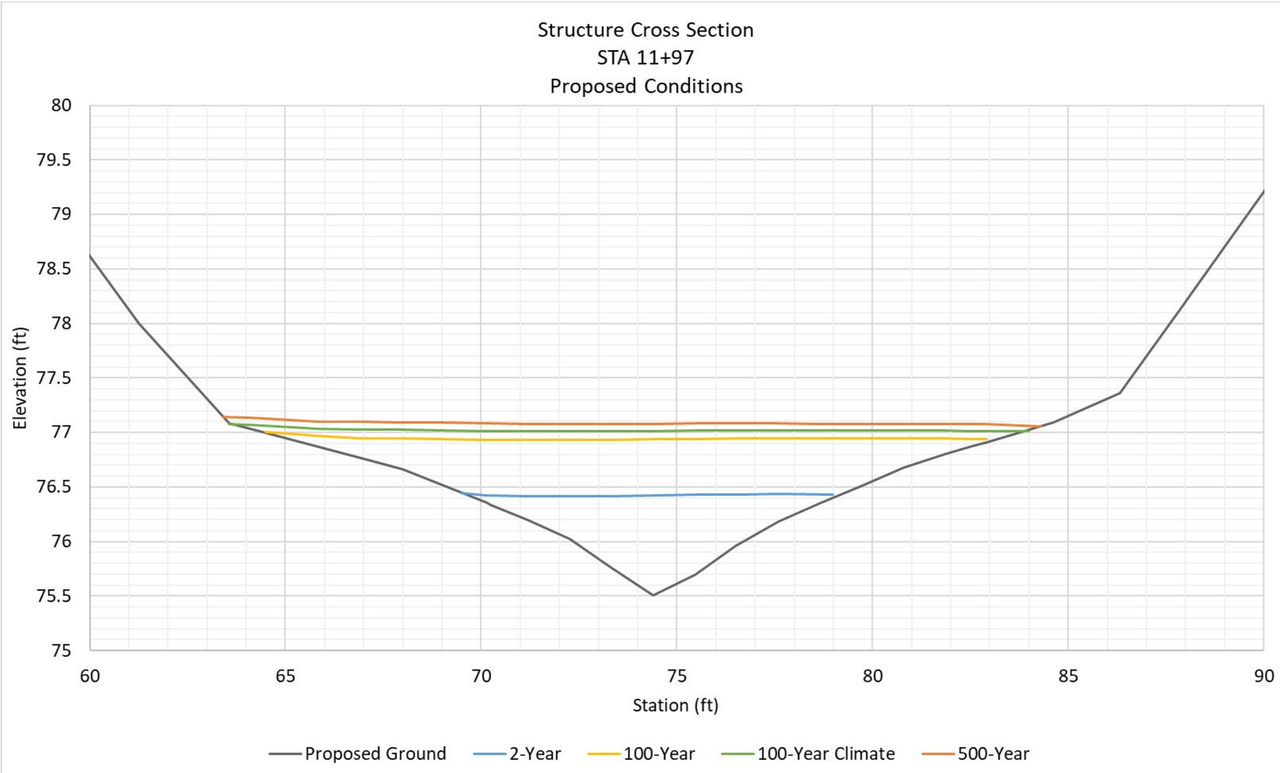

Figure 6: Typical section through proposed structure

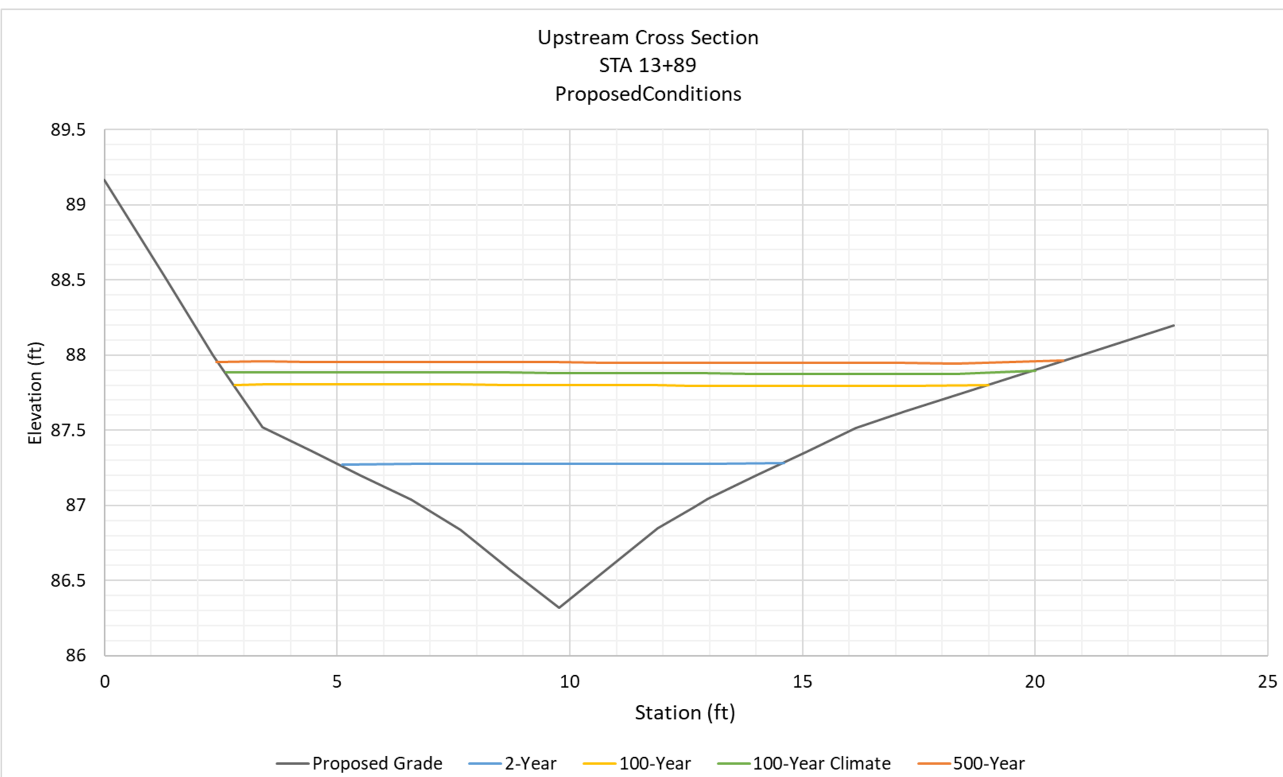

Figure 7: Upstream of proposed structure cross section

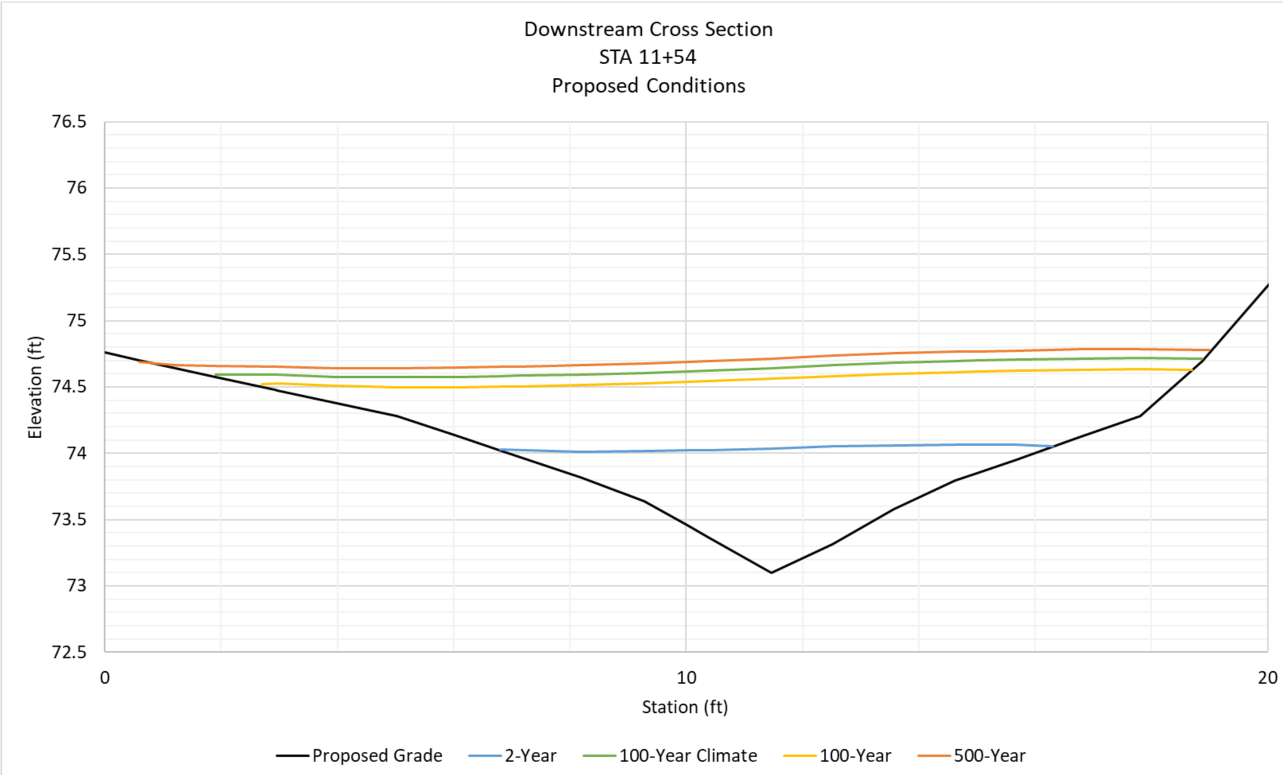

Figure 8: Downstream of proposed structure cross section

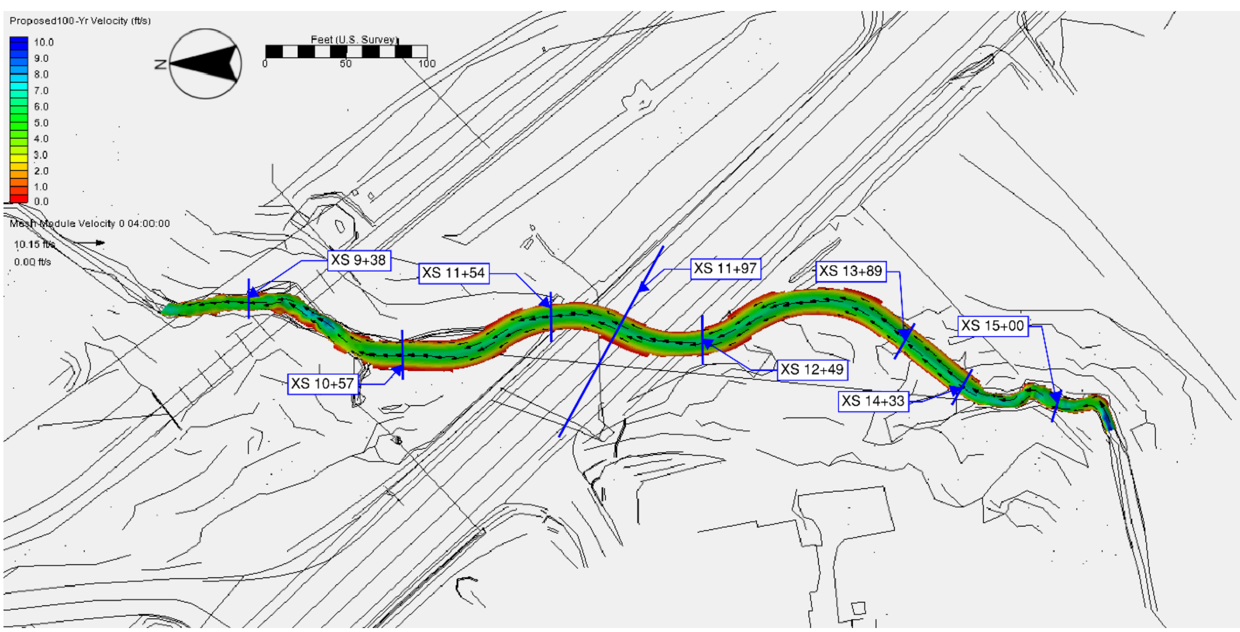

Figure 9: Proposed-conditions 100-year velocity map

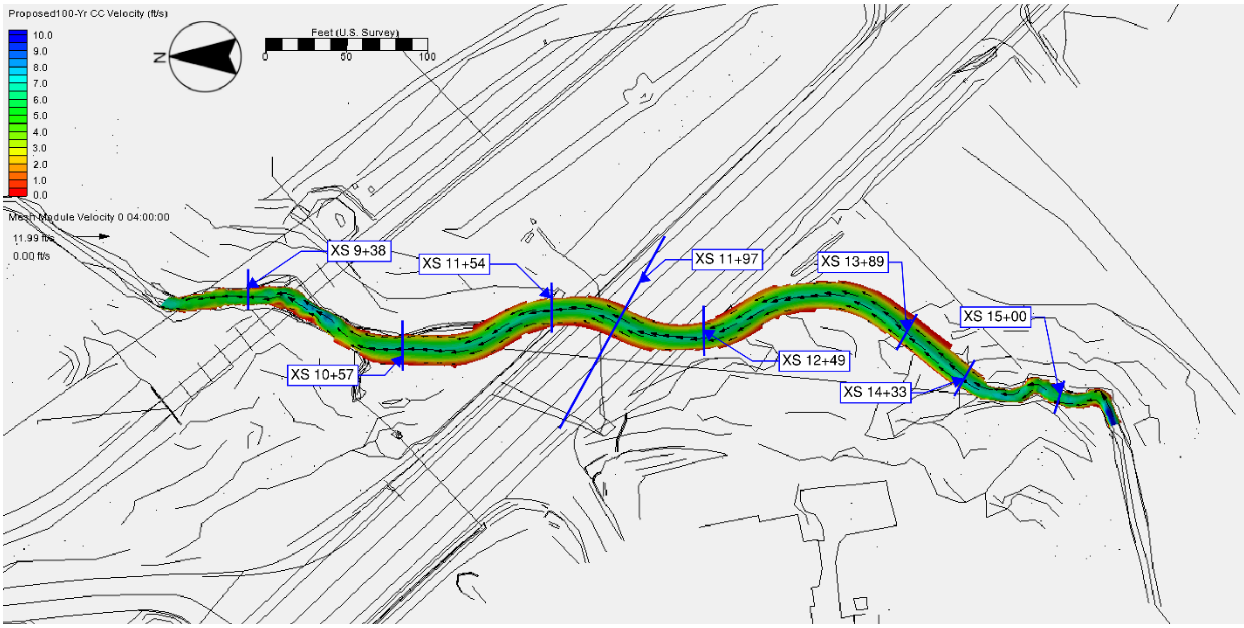

Figure 10: Proposed-conditions 100-year CC velocity map

8 Fish Passage Design Methods Selection

8.1 Design Methodology Selection

See Section 8.1 for September 2020 PHD.

8.2 Bridge Design Criteria

See Section 8.2 for September 2020 PHD.

8.2.1 *Confined Bridge Design Width Criteria*

See Section 8.2.1 for September 2020 PHD. With a revised bankfull width of 13 feet, the stream simulation calculation yields a starting hydraulic opening of 18 feet. The increase of bench widths on both sides of the stream to 5-foot to accommodate wildlife connectivity yields an overall minimum hydraulic opening of 23-feet and a corresponding factor of safety of 1.8.

8.2.2 *Backwater and Freeboard*

The WCDG recommend the prevention of excessive backwater rise and increased main channel velocities during floods that might lead to scour of the streambed and coarsening of the stream substrate, allow the free passage of debris expected to be encountered, and generally suggests a minimum 3-foot freeboard for a bridge structure. Due to the difference in roadway crest and stream thalweg elevations, it is practicable to meet the minimum 3 feet of freeboard at this crossing. With a proposed roadway crest at the hydraulic opening of 110.5 feet and a girder width of 5.5 feet, the conceptual bridge low-chord is 105 feet. The water surface elevation (WSE) at the upstream end of the conceptual bridge location is 80 feet for the 100-year flow, giving an estimated freeboard of 25 feet, however, freeboard requirements need to accommodate the projected 100-year for 2080. Refer to section 11.4 for freeboard as relates to the anticipated 2080 flow. Additionally, a minimum of 6 feet above the channel thalweg should be provided for constructability, future maintenance, and performing monitoring activity which is easily achieved with a bridge structure.

8.2.3 *Channel Planform and Shape*

The proposed channel planform has been designed to mimic the planform within the reference reach identified in the PHD. Due to the length of proposed regrade, the planform upstream and downstream of the reference reach was used to inform the corridor and channel sinuosity in the proposed design. Both the main channel and corridor exhibit matching sinuosity due to long term incision of the channel. This average wavelength, meander amplitude, and radius of curvature of the stream corridor sinuosity was mimicked in the proposed design. The average wavelength was determined to be 154 feet, average meander amplitude was 22 feet, and the average main channel meander radius of curvature was 71 feet. The main channel has been designed to meander with the corridor, with variable floodplain bench width.

The proposed channel cross-section remains similar to the PHD, except for increase of bench widths from 3 feet up to 5 feet to provide for wildlife connectivity. The proposed channel cross section geometry includes, from centerline, a 4 (H) to 1 (V) slope offset 2.5 feet, which transitions to 7 (H) to 1 (V) offset 4 feet, which transitions to a 10 (H) to 1 (V) bench that varies from 0 feet to 10 feet in width as the main channel meanders within the corridor. The overall minimum hydraulic opening width was increased from 18 feet to 23 feet to provide two 5-foot benches to accommodate wildlife connectivity through the crossing.

8.2.4 *Floodplain Continuity and Lateral Migration through Structure*

See Section 8.2.4 for September 2020 PHD.

8.2.5 *Channel Gradient*

The proposed channel gradient is 5.63 percent. This has been revised from the PHD concept stream profile of 5.73 percent. In comparison to the immediate 120 feet of channel surveyed upstream of the crossing, the proposed crossing shows a slope ratio of 1.02 (5.63 percent proposed/5.53 percent upstream), which is the same as is reported in the PHD. This slope ratio remains below the maximum recommended value of 1.25 for stream simulation designs.

9 Streambed Design

9.1 Proposed Alignment

The proposed horizontal alignment begins 20 feet downstream of the existing culvert outlet and ends 10 feet upstream of the existing culvert inlet. The proposed design replaces 390 feet of existing open and culverted channel with 418 feet of channel as measured along centerline. The proposed alignment incorporates stream corridor and main channel meander. The overall bearing of the stream corridor through the crossing is the same as the existing culvert but shifted immediately to the east. Outside of the roadway prism, flexibility in the proposed channel alignment is limited due to the depth of the existing channel ravine. The alignment was designed to limit the need for significant cut into the ravine walls.

9.2 Proposed Section

Refer to Section 8.2.3 for information on the proposed channel section.

9.3 Bed Material

See **Appendix A** for September 2020 PHD.

9.4 Channel Habitat Features, Large Woody Material

LWM metrics have been updated to the revised channel alignment and overall channel regrade length. The proposed concept stream plan has a regrade length of 418 feet which results in design targets of 14 key pieces, 48 total LWM pieces, and 165 cubic yards of LWM. Refer to Appendix C which shows a concept layout of the LWM. The plan depicts 71 pieces with 47 of those being key pieces for a total volume of 167 cubic yards which exceeds the Fox and Bolton 75th percentile recommendations. The pieces are distributed over the length of the proposed construction and are not shown within the structure crossing footprint. Final piece sizing and placement of the LWM shall be determined during final design.

10 Floodplain Changes

This project is not within a mapped floodplain. The 100-year pre-project and expected post-project conditions were evaluated to determine whether there would be a change in the WSEL and floodplain storage. The confined cross section and high slope result in minimal backwatering in the pre-project condition. The proposed crossing is expected to decrease the WSEL upstream of the crossing and eliminate all backwatering.

10.1 Floodplain Storage

Installation of a proposed structure would eliminate backwater upstream of the existing culvert, resulting in a lower water surface elevation. Figure 11 is the difference in water surface between the 100-year existing and proposed conditions. There is a reduction in the water surface at the entrance of the culvert of approximately 2 feet and a slight increase at the downstream outlet. The WSEL match between the existing and proposed approximately 50 feet upstream of the structure entrance. Figure 12 and Figure 13 illustrate the change in water surface elevation upstream and downstream of the crossing respectively. The majority of the upstream and downstream reaches have very minimal change in WSE. Subtle increases in the downstream reach can be attributed to the difference in the mesh area in SMS.

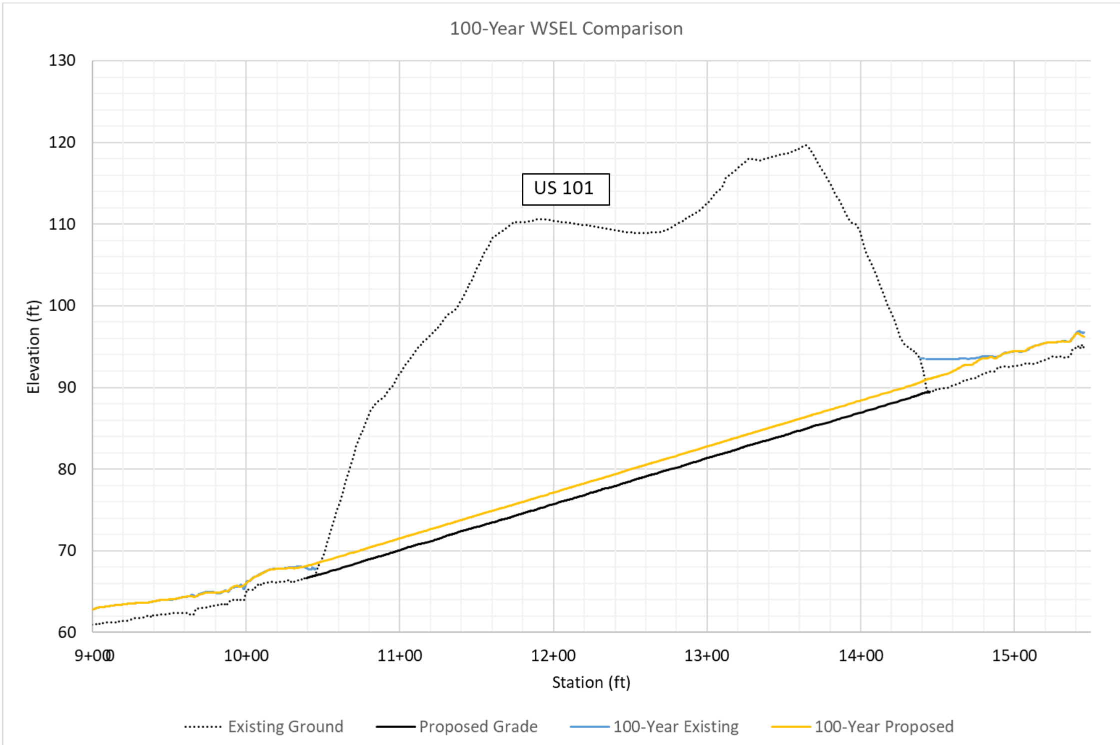

Figure 11: Existing and proposed conditions 100-year water surface profile comparison

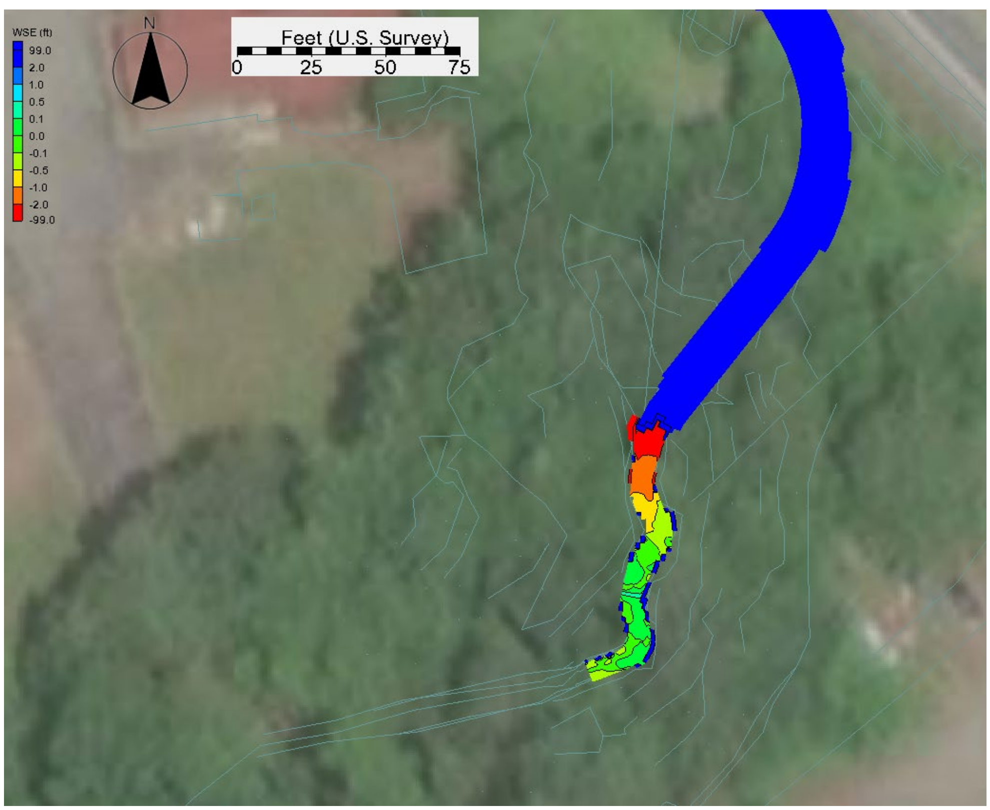

Figure 12: 100-year upstream water surface elevation change from existing to proposed conditions

Positive values indicate an increase in water surface elevation from existing to proposed conditions. Blue (2-99 ft) represents new water surface extents wet under proposed conditions but not in existing conditions

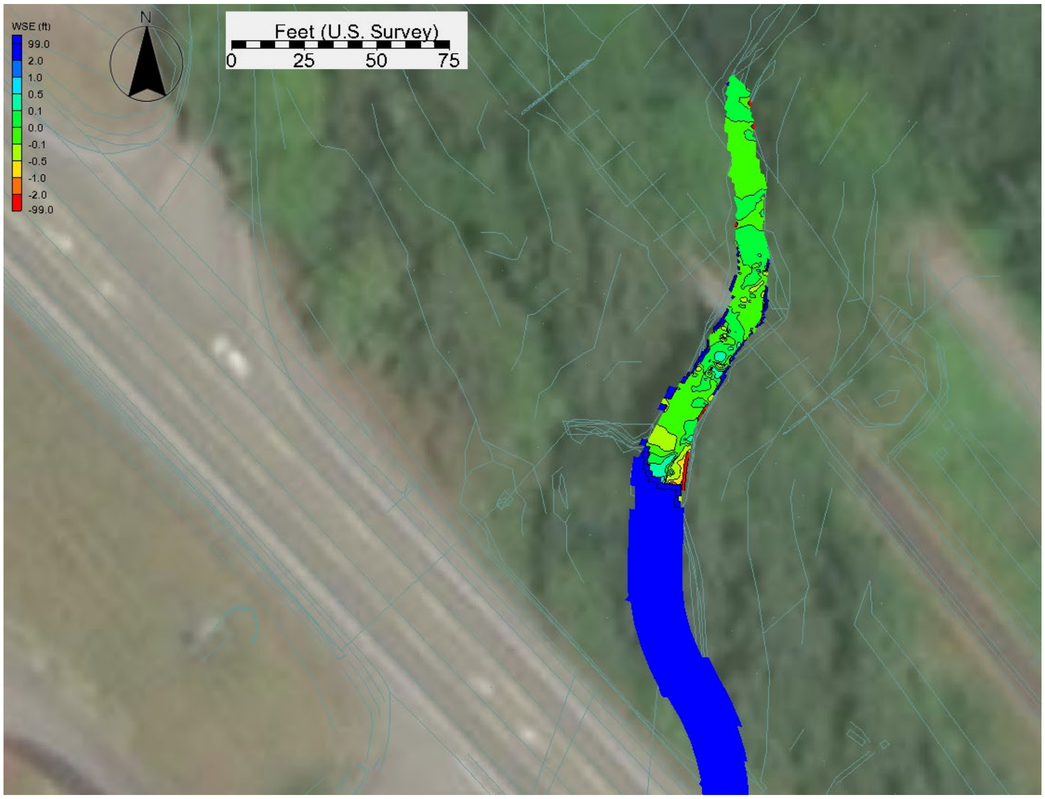

Figure 13: 100-year downstream water surface elevation change from existing to proposed conditions

Positive values indicate an increase in water surface elevation from existing to proposed conditions. Blue (2-99 ft) represents new water surface extents wet under proposed conditions but not in existing conditions

11 Climate Resilience

WSDOT recognizes climate resilience as a component of the integrity of its structures and approaches the design of bridges, and buried structures through a risk-based assessment beyond the design criteria. For bridges and buried structures, the largest risk to the structures will come from increases in flow and/or sea level rise. The goal of fish passage projects is to maintain natural channel processes through the life of the structure and maintain passability for all expected life stages and species in a system.

11.1 Climate Resilience Tools

WSDOT also evaluates crossings using the mean percent change in 100-year flood flows from the WDFW Future Projections for Climate-Adapted Culvert Design program. All sites consider the 2080 percent increase throughout the design of the structure.

11.2 Hydrology

For each design, WSDOT uses the best available science for assessing site hydrology. The predicted flows are analyzed in the hydraulic model and compared to field and survey indicators, maintenance history, and any other available information. Hydraulic engineering judgment is used to compare model results to system characteristics. If there is significant variation, then the hydrology is re-evaluated to determine whether adjustments need to be made, including adding standard error to the regression equation, basin changes in size or use, etc.

In addition to using the best available science for current site hydrology, WSDOT is evaluating the structure at the 2080 predicted 100-year flow event to check for climate resiliency. The Design Flow for the crossing 57.2 cfs at the 100-year storm event. The projected increase for the 2080 flow rate is 29.9%, yielding a projected 2080 flow rate of 74.3 cfs.

11.3 Structure Width

The 23-foot structure width was evaluated at the 100-year flow event, projected 2080 100-year flow event, and 500-year flow event and determined to produce less than 10% increase in velocities through the structure and upstream reaches. The increase in velocities does not warrant an increase in structure width. Refer to Table 2 under section 7.2.

11.4 Freeboard and Countersink

The minimum recommended freeboard at this location is 3-feet at the 100-year flow event. As mentioned under 8.2.2, due to the grade difference between the road and thalweg, meeting freeboard requirements with a bridge structure is achievable. The water surface elevation is projected to increase by 0.3 feet for both the 2080 projected 100-year flow rate and the 500-year flow rate. Due to the minimal increase and additional requirements for maintenance and wildlife connectivity vertical clearance, the crossing will accommodate projected climate change impacts.

11.5 Summary

The minimum hydraulic opening of 23 feet and a minimum freeboard of 3 feet allows for the channel to behave similarly through the structure as it does in the adjacent reaches under the projected 2080 100-year flow event and the 500-year event. Model results show that climate flow velocity increases are minor. Due to the large elevation difference between the road and streambed, freeboard will not be an issue.

Appendices

Appendix A: September 2020 PHD

Appendix B: SRH-2D Model Results

Appendix C: Large Woody Material Plan Sheet

Appendix D: Stream Plan Sheets, Profile, Details

Appendix A: September 2020 PHD

US 101 MP 268.54 Discovery Creek: Preliminary Hydraulic Design Report

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US 101 Discovery Creek Tributary to Sequim Bay Fish Passage
MP 268.54 Discovery Creek (UNT to Sequim Bay) Creek
Preliminary Hydraulic Design Report
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1.0 Introduction and Purpose

To comply with United States, et al vs. Washington, et al No. C70-9213 Subproceeding No. 01-1 dated March 29, 2013 (a federal permanent injunction requiring the State of Washington to correct fish barriers in Water Resource Inventory Areas (WRIAs) 1-23), the Washington State Department of Transportation (WSDOT) is proposing a project to provide fish passage at the US 101 crossing of Unnamed to Tributary to Sequim Bay (locally known as Discovery Creek) at Mile Post (MP) 268.54. This existing structure on US 101 has been identified as a fish barrier by Washington Department of Fish and Wildlife (WDFW) and WSDOT Environmental Services Office (ESO) (Site ID 991667) due to excessive slope and has an estimated 3.23 miles of habitat gain .

Per the injunction, and in order of preference, fish passage should be achieved by (a) avoiding the necessity for the roadway to cross the stream, (b) use of a full span bridge, or (c) use of the stream simulation methodology. WSDOT evaluated design options as defined in the injunction. Avoidance of the stream crossing was determined to not be viable given the location of the highway and the need to maintain this critical transportation corridor. WSDOT is proposing to replace the existing crossing structure with a structure designed using the confined bridge design methodology.

The Discovery Creek water crossing structure is located in Clallam County 4.2 miles east of Sequim at milepost 268.54 of US 101 in Washington Water Resource Inventory Area (WRIA) 17 on the Olympic Peninsula. The highway runs east to west at this location. Discovery Creek is a first order stream that generally flows north beginning on Burnt Hill (elevation 2200 feet) crosses US 101 (upstream elevation 89 feet) over a distance of 3.36 stream miles (See Figure 1 for the vicinity map).

The proposed project will replace the existing 48 inch/36 inch diameter, 361 foot-long concrete and corrugated metal pipe culvert, with a minimum of a 23 foot wide opening. For hydraulic purposes, 17 feet is needed; however, Wildlife Habitat Connectivity was also assessed at this crossing. This segment of highway has been ranked high for investments based on ecological priority. There is a recommendation to maintain a 5 foot wide bench above the 2-year flow on each side of the creek. The channel cross section necessary for hydraulic purposes includes a 2 foot wide bench on each side, so an additional 6 feet is being to the channel cross section to accommodate wider benches for wildlife. This document shows a 17 foot cross section for hydraulic purposes and the modeling will be updated after the PHD phase to show the full 23 feet at a minimum.

Due to the length of structure and fill depth, WSDOT Headquarters Hydraulics is recommending a bridge structure be utilized for this crossing. The proposed structure for the Discovery Creek is designed to meet the requirements of the federal injunction utilizing the confined bridge design criteria outlined in the 2013 WDFW Water Crossing Design Guidelines (WCDG).

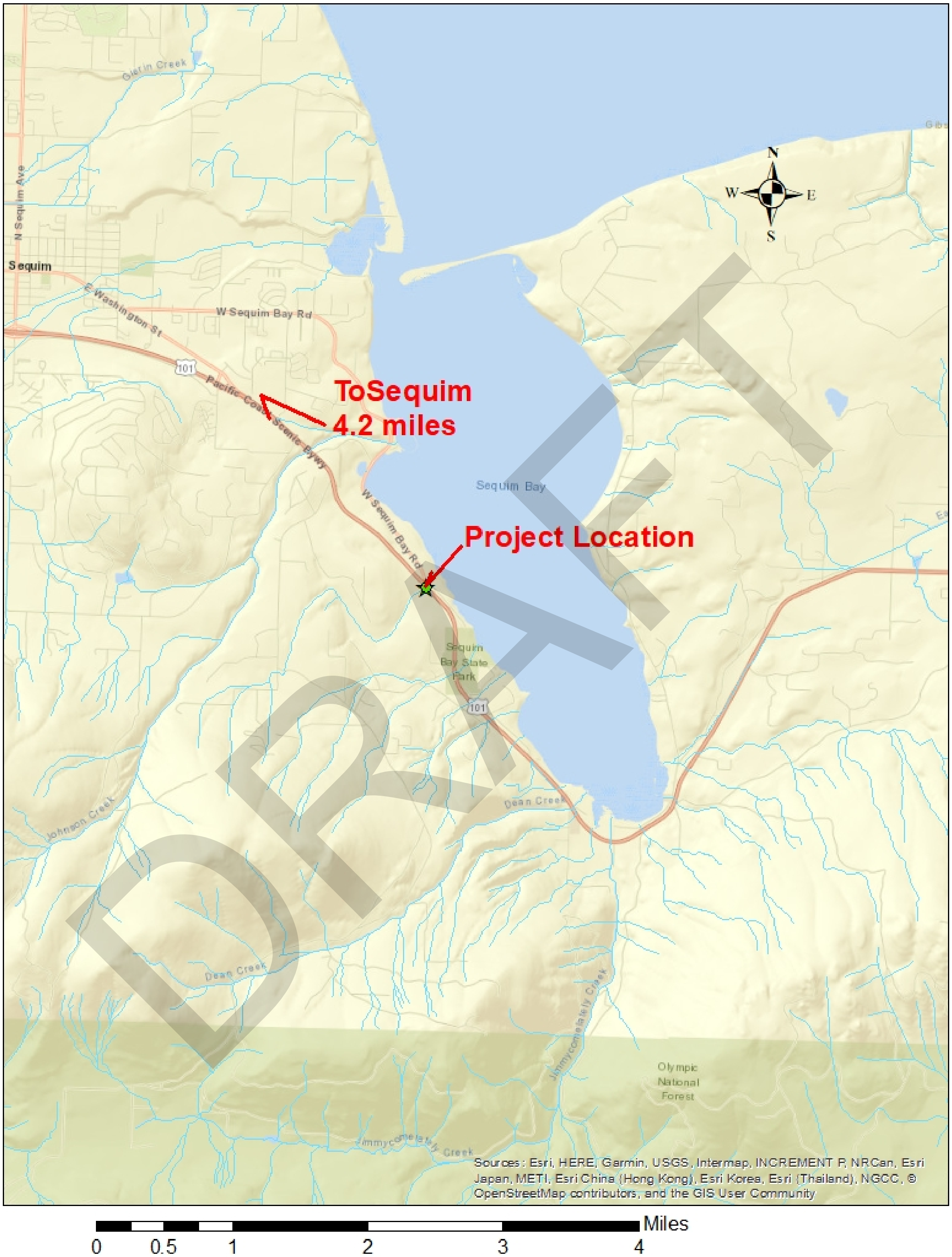

Figure 1 Vicinity map

2.0 Site Assessment

Headquarters Hydraulics, North Central Region (NCR) Design Office, WDFW, NCR Environmental and Port Angeles Project Office visited the site on February 18, 2014 to assess project needs and measure bankfull width. The agreed upon field measured bankfull width during this site visit was 12 feet. Headquarters Hydraulics, ESO, and NWR Hydraulics visited the site on March 13, 2018 to confirm site conditions. The average bankfull width during this site visit was 9 feet. The previously agreed upon 2014 bankfull width will be used for design purposes.

The US 101 Discovery Creek crossing conveys Discovery Creek under US 101 near Mile Post 268.54. The crossing consists of a 363 foot long; 4-foot diameter corrugated metal pipe (CMP) pipe upstream section connected to a 3-foot diameter concrete pipe, likely through a catchbasin that was not located during survey. The length of each material type is unknown (see the inlet and outlet photos Figure 2). The owner of the Sequim Bay Lodge installed an extension onto the WSDOT culvert in the early 1990s and is the owner of that extension.

Figure 2 Photo showing 4' CMP inlet (left) and 3' concrete pipe at outlet (right)

The US 101 crossing culvert is identified as a barrier because of excessive outfall drop, high velocity at fish passage design flows and the low flow depth is less than the minimum allowed by WDFWs Fish Passage Inventory, Assessment and Prioritization Manual. The culvert is placed at 5.9% and has an unknown transition between the two culvert types.

The Sequim Bay Lodge is located on the southwest side of the existing culvert as shown in Figure 3 below. This lodge could be a constraint during design and construction, as further discussed in Section 8.3.

Figure 3 Sequim Bay Lodge Location Compared to Existing Culvert

Approximately 144 feet downstream of the inlet, there is a grate inlet that discharges vertically at the roof of the culvert that conveys roadway runoff from US 101 and the nearby hillside runoff into Discovery Creek (See Figure 4).

Discovery Creek flows in a deep ravine for the first 0.7 miles of the upstream reach. Then the stream goes through open fields and through ponds in a shallow channel for another 0.6 miles and flows into a very deep incised channel for the rest of the downstream reach up to its final discharge point, Sequim Bay (see Figure 5 for the 2002 bare-earth LiDAR image of the creek and project area).

Approximately 0.37 miles upstream of the US 101 crossing, there is a private earth fill dam with a road going over the top. It has 2 culvert spillways. The first is a 1.5 foot diameter CSP with a channel dug out that meets with the main channel 120 feet downstream. There is no outfall drop for this culvert. The second pond outlet is a 12 inch CMP culvert (Site ID 999676) has a 9.5 foot drop at the outlet (See Figure 6 left).

Approximately 0.5 miles upstream of US 101 crossing, the creek passes through a private pond and another 0.5 mile upstream from the private pond it passes through a water supply dam and culverts (see Figure 6 right).

Figure 4 Grate Inlet at the roof of US 101 Discovery Creek Crossing Culvert

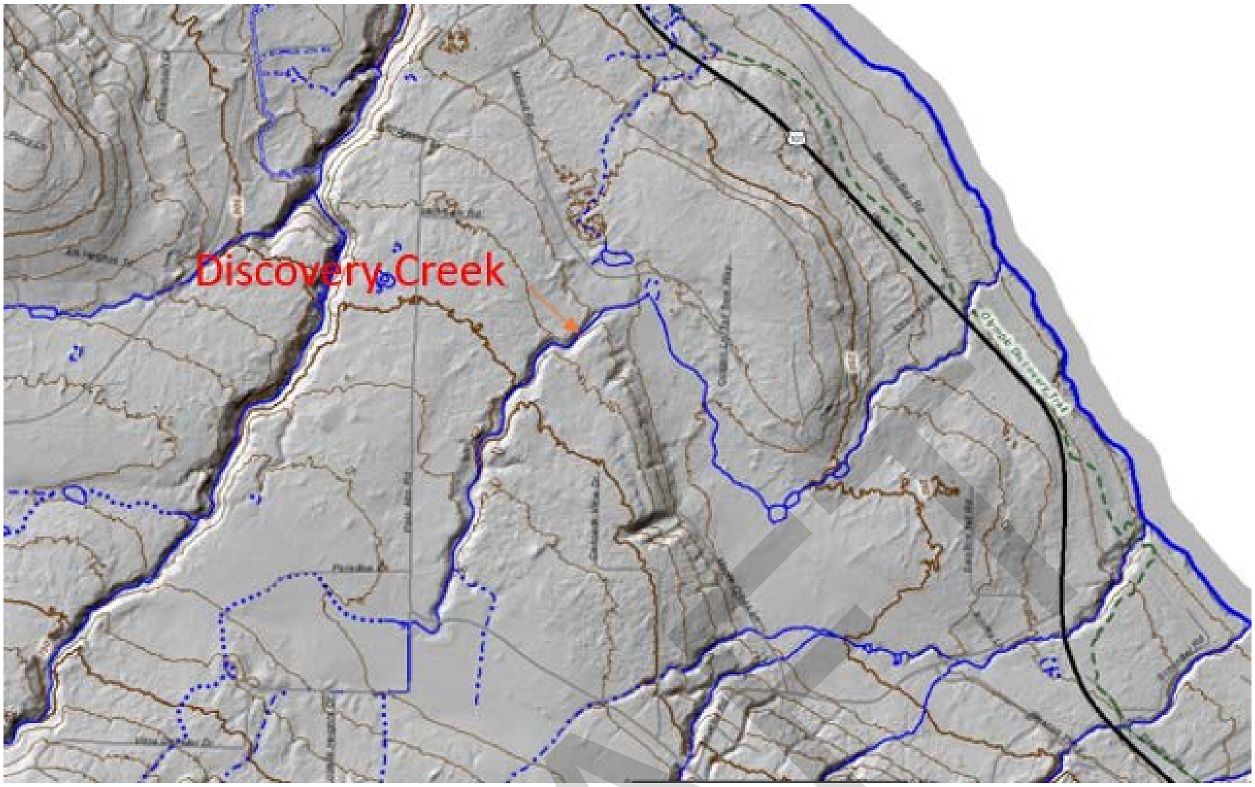

Figure 5 LiDAR image of Discovery Creek showing incised channel upstream and downstream connected with open field in the middle.

Figure 6 Upstream fish barriers Site I.D # 999676 (left) and Site I.D. # 999682 (right)

The downstream channel consists mostly of fines and gravels, the left and right banks are steep and the channel is incised. The culvert has an outfall drop of about 0.8 ft. There is a pedestrian bridge (Olympic Discovery Trail, on a refurbished railroad trestle) downstream of the crossing with piling driven into the stream bed. A natural channel-spanning log jam has developed approximately 193 feet downstream of the crossing, creating a 2.5 foot water surface elevation (WSE) drop (see Figure 7).

Figure 7 Log Jam and Cascade Located 225 ft Downstream from the US 101 Culvert Outlet

Further downstream, there two private culverts which are known fish barriers as delineated by WDFW. The first one is located approximately 550 feet downstream from US 101 Crossing outlet, and is a 4 foot diameter culvert @ 0.49% slope having a 7-foot WSE drop (see Figure 8 left). The second one is located approximately 100 feet downstream of the first culvert and is a 4.5-foot diameter culvert @ 1.58% slope with 5.5-foot WSE drop (see Figure 8 right). Bedrock is exposed at the outlets of both culverts.

Figure 8 Downstream fish barriers Site I.D. # 994321 (left) and Site I.D. # 9943322 (right)

The prevailing slope upstream and downstream of the US 101 crossing is approximately 6.1% and 5.5%, respectively. Once the US 101 culvert is replaced and the various barriers downstream and upstream removed, the stream has a potential natural regrade to about a 6.1% slope. A plot of a long profile generated from a 2002 and a 2012 LiDAR data and WSDOT survey is included in Appendix F of this report.

3.0 Watershed Assessment

3.1 Watershed & Landcover

The headwaters of Discovery Creek lie on the northern flank of Burnt Hill at approximately 2170 feet above sea level. The watershed size is estimated at 1026 acres (1.6 square miles) from its headwaters to US 101. The size of the Discovery Creek watershed was estimated by initially using Streamstats to convert 10m DEM to a drainage basin, and then using topographic maps in the upper watershed and bare-earth LiDAR in the lowlands to adjust the watershed boundaries. From its headwaters, Discovery Creek flows northeast through a densely forested ravine on the north flank of Burnt Hill at 5% gradient until reaching a flat plateau called Happy Valley, where the gradient gets flatter to 3.6% before it gets steeper to 6.1% for 0.5 miles upstream of the US 101 crossing and then 5.5% downstream of the US 101 crossing.

Discovery Creek is an 2nd order drainage that flows to marine water entering Sequim Bay approximately 1.4 miles south of Johnson Creek and approximately 2.0 miles north of Dean Creek. It is located in the watershed of WRIA 17.03. Discovery Creek has a watershed area of 1.6 sq. mi (See Figure 9). The elevation of the Discovery Creek watershed ranges from about 90 feet (NAVD88) at the US 101 crossing to about 2200 feet (NAVD88) at the summit of Burnt Hill.

The land use in the drainage is 71% commercial forest or private woodlots, with pasture/grassland representing 12% and rural residential housing representing 17%. The watershed is zoned by Clallam County as Rural Conservation (RC) at 1.7%, Conservation Forest (CF) at 22%, Rural 5 (R5) at 31%, and Rural Neighborhood Conservation (NC) at 45%. No land within the Discovery Creek watershed is within an Urban Growth Area, being located just east of the Sequim UGA. Therefore, under current zoning, no rapid increase in urban or suburban development is anticipated (see Figure 10).

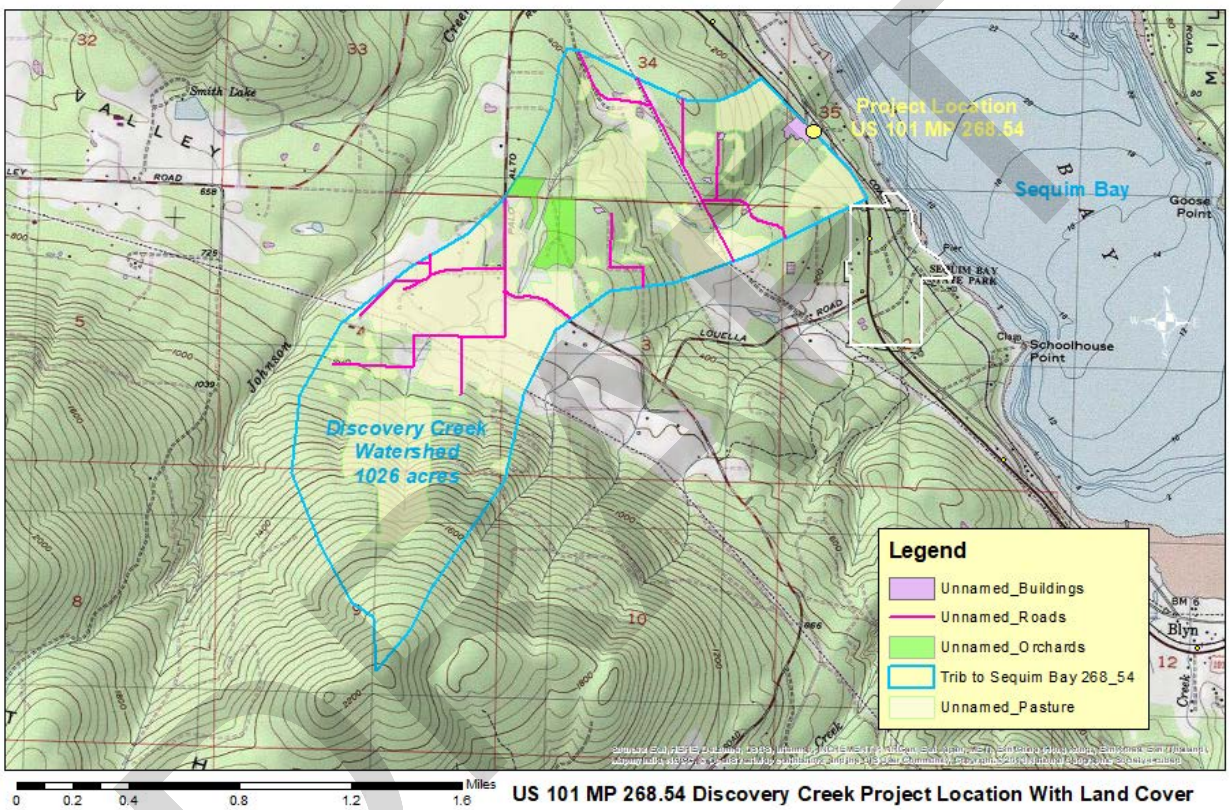

Figure 9 US 101 MP 268.54 Discovery Creek Project Location with Land Cover

Figure 10 Discovery Creek Drainage Area

3.2 Mapped Floodplains

This project is not within a mapped FEMA jurisdictional floodplain. Discovery Creek resides in a deep, incised ravine both up and downstream of the US 101 culvert. Due to confined nature of these stream reaches, changes to the constructed channel are not expected to affect adjacent properties.

3.3 Geology & Soils

The geology of the Discovery Creek watershed has the typical characteristics of fluvial systems that occupy the northern tier of the Olympic Peninsula: Pleistocene glacial drift mantled over Eocene volcanic rocks of the Crescent Formation with small, localized areas of mass wasting. The Crescent Formation only reaches the ground surface in the watershed near the apex of Burnt Hill to the south. Figure 11 illustrates the distribution of geologic contacts in the Discovery Creek watershed.

The USDA Web Soil Survey indicates that the soils in the project area surrounding the US 101 Discovery Creek culvert is comprised of 88% Hoypus gravelly sandy loam and 12% Yeary gravelly loam. These soil types are both the weathering products of glacial drift. The Hoypus occupies the lowlands and terraces near US 101.

The Discovery Creek watershed is comprised of 3 mapped geologic formations – Vashon glacial drift (73.0%), basalt of the Crescent Formation (25.6%), and marine sedimentary rocks of the Makah Formation (1.5%). Discovery Creek crosses surface lobes of the Makah approximately 640 feet upstream of the US 101 crossing, and 560 feet downstream. It is a possibility that bedrock of the Makah Formation could be encountered during excavation associated with the US 101 culvert replacement project. Geotechnical borings would be needed to make a definitive assessment.

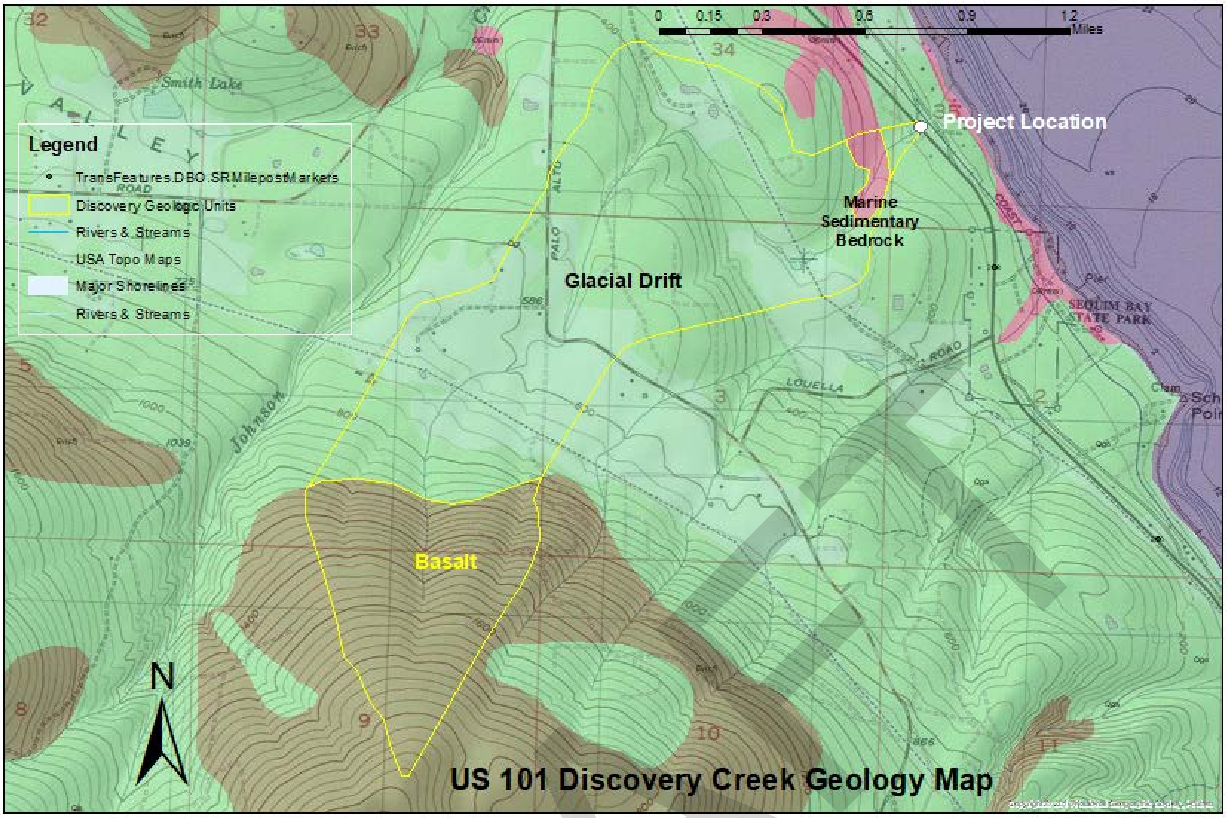

Figure 11 US 101 MP 268.54 Discovery Creek Surface Geology

3.4 Geomorphology

3.4.1 Channel Geometry

Discovery Creek crossing US 101 east of Sequim, WA has a single thread channel that is deeply incised both up and downstream of US 101 and is completely disconnected from any historic floodplain. Upstream of the US 101 culvert, Discovery Creek flows through 6 impassable culverts, 5 partially passable culverts, 2 fully passable culverts, 3 impoundments and one “natural” barrier (a 9 foot drop waterfall) located on private roads, driveways, and the county owned Palo Alto Road. These culverts not only prevent fish passage, but also pin down the alignment of Discovery Creek and impedes the transport of stream sediments. The riparian area of Discovery Creek both up and downstream of US 101 has a full tree canopy and wood has been recruited by natural processes to reside within and along the margins of the stream channel in some locations.

Figure 12 Discovery Creek Channel Upstream of the US 101 Culvert Inlet (Typical Section)

Upstream of Palo Alto Road, the channel geometry on Discovery Creek changes significantly, transitioning from a deeply incised (see Figure 12), fully forested ravine to a broad parabolic grassy swale through a mostly- treeless plateau known locally as Happy Valley. The land in Happy Valley has been cleared of trees for farming and ranching, and is dominated by reed canary grass and pastures, as shown in Figure 13 below.

Figure 13 Discovery Creek North of Palo Alto Road with Burnt Hill in the Background

Downstream of the US 101 culvert, Discovery Creek flows east-west crossing under the Olympic Discovery Trail, a high railroad trestle that is not classified as a fish barrier, before flowing through 2 impassable fish barriers on W. Sequim Bay Drive and a privately-owned drive, and eventually into the Strait of Juan de Fuca just north of Sequim Bay State Park. Figure 14 shows the downstream water surface drop and channel incision.

Figure 14 Discovery Creek US 101 Culvert Outlet, Illustrating the WSE Drop

3.4.2 Potential for Aggradation, Incision and Headcutting

Discovery Creek lies in a steeply incised ravine in the project reach. In addition, downstream of the US 101 crossing, former floodplain terraces are up to 6 feet above the active channel, indicating incision. Some of these terraces have mature conifers on them, suggesting that the bulk of the incision occurred decades ago. The historic down cutting in Discovery Creek near US 101 is related to a combination of minor isostatic rebound from continental glaciation, large-scale logging, and debris removal from the stream as the area was settled by settlers. Evidence of this is displayed upstream of Palo Alto Road in Happy Valley where large areas of land has been permanently cleared of trees and converted to pasture (see Figure 13). The Washington Coastal Resilience Project (2018) indicates that the region near Sequim Bay is currently considered “stable” (-0.5 to 0.5mm/year) for vertical land movement. There is also evidence of a more recent phases of incision downstream of the two private driveway culverts downstream of US 101, but also in a reach about 200-500 feet downstream of the crossing. Debris avalanches and slides occur occasionally within the ravine.

The replacement of the current 3-foot diameter corrugated metal culvert with a 23 foot-wide opening will eliminate backwatering but may destabilize the equilibrium conditions and result in channel degradation, head cutting, and bank erosion. Providing channel roughness and bank protection features such as log jams, root wads, hyporheic logs, habitat boulders, and intensive bioengineering on the stream banks and within the channel need to be incorporated into the final designs to prevent or reduce large-scale channel alterations during high flows.

The private culverts downstream have incised to bedrock, thus limiting the risk of additional degradation. If any fish passage efforts are undertaken at either culvert, aggrading the stream channel will be a necessary component, given the 6+ foot elevation drops at the outlets. Thus these culverts do not represent a risk of degradation for the US 101 crossing. However, the log jam 200 feet downstream of the crossing may destabilize over time. The key piece holding the streambed is fractured and its embedding is tenuous. Stream design should consider the potential degradation related to failure of the log jam.

3.4.3 Floodplain Flow Paths

North (downstream) and south (upstream) of the US 101 Discovery Creek culvert crossing the channel is deeply incised and is completely disconnected from any historic floodplain that may have previously existed. FEMA has not completed a flood hazard study for Discovery Creek or Sequim Bay and there is no regulatory floodplain as a result.

3.4.4 Channel Migration

Much of the alignment of Discovery Creek and its tributaries are stationary upstream of the US 101 culvert due to channel incision and the positioning of culverts within the tributaries, rendering them stationary. Downstream of US 101, Discovery Creek is deeply incised until it approaches Sequim Bay near Sequim Bay State Park, precluding any opportunity for large-scale channel migration.

3.4.5 Existing LWM and Potential for Recruitment

The Discovery Creek ravine has a nearly intact riparian corridor with dense understory plants. The Discovery Creek watershed has a measured 71% tree canopy cover. Discovery Creek has a nearly continuous riparian forest (likely due to being in a ravine) in a mixed second and old growth forest. Along the upstream Discovery Creek tributaries, riparian cover is discontinuous and narrow due to land clearing for low-density residential development and agriculture on the uplands in Happy Valley. North (downstream) of the US 101 culvert, The narrowness of the ravine and the sheer sizes of the large conifer trees in the riparian zone, some up to 4 feet DBH, would likely span the entire stream channel when recruited by windfall, sloughing, or mass wasting.

3.4.6 Sediment Size Distribution

Discovery Creek is a gravel and cobble bed stream. Gravel and cobble bed streams usually have surface sediment that is coarser than the sediment below the surface. The degree of difference between surface and subsurface sediment is tied to the flow regime and upstream sediment supply.

The ratio of surface sediment size to the size of subsurface sediment (D50surf/D50sub) is a good indicator of the nature of the sediment transport of the Stream. A value of the ratio D50surf/D50sub close to 1 indicates high sediment supply, while values larger than 1 indicate low sediment supply. It can be also used to characterize the stream if it is aggrading or degrading. In Aggrading streams, subsurface is similar in size to bedload, but in degrading streams, subsurface sediment is coarser than bedload (Lisle 1995).

Therefore, the project team collected samples from both armor layer and sublayer to characterize the stream and use the data for streambed mix design. The details of the sampling methods and results are presented below.

A composite sediment sample was taken in the Discovery Creek streambed at 3 locations upstream of the existing US 101 culvert. The samples were taken at 65 feet, 90 feet, and 110 feet upstream of the culvert, considered by field observations to be outside of the hydraulic influence of the culvert entrance. This reach constitutes the unofficial reference reach for Discovery Creek. An armor layer was found in Discovery Creek. Armoring occurs when the bed surface of gravel-bed streams and rivers is coarsened relative to the subsurface, and is caused by winnowing and saltation of fines during low flows. The top 2-3 inches of the cobble armor layer was initially removed to reveal the core streambed sediment. The composite samples were taken with the armor layer removed. The composite streambed sediment sample was given a sieve by WSDOT's Materials Laboratory in Tumwater, WA on 3/21/2019. The results are shown in Figure 15 and Table 1. The Sieve analysis results show that the core sediment substrate is dominated by fine sediments.

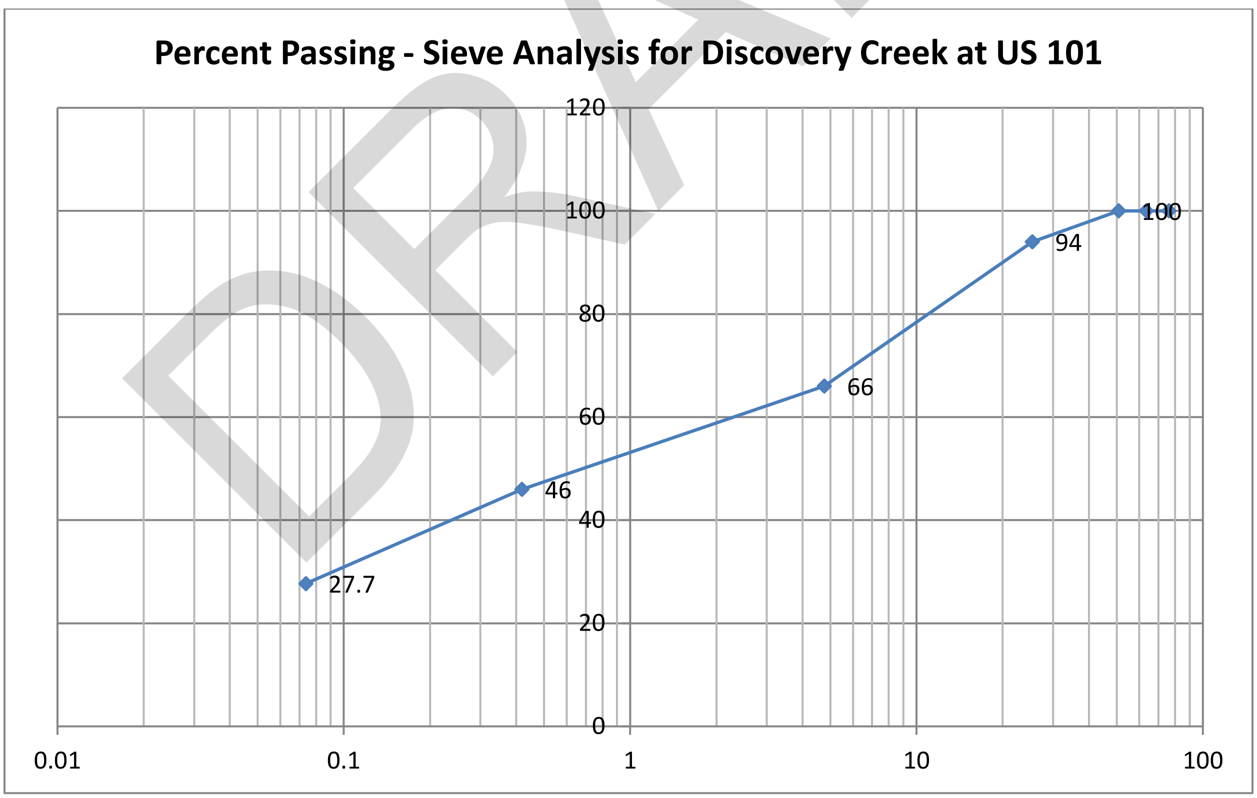

Figure 15 Sediment Properties Below Armor Layer

Table 1 Sediment Properties Below Armor Layer

Sieve Sizes (in)	Pct Passing
2.5	100
2.0	100
1.0	94
0.187 (No. 4)	66
0.0165 (No. 40)	46
0.0029 (NO. 200)	27.7

A second site visit was done on Sept 2019 to perform a pebble count that captures the sediment that was part of the armoring layer. Figure 16 and Table 2 show the results of the pebble count.

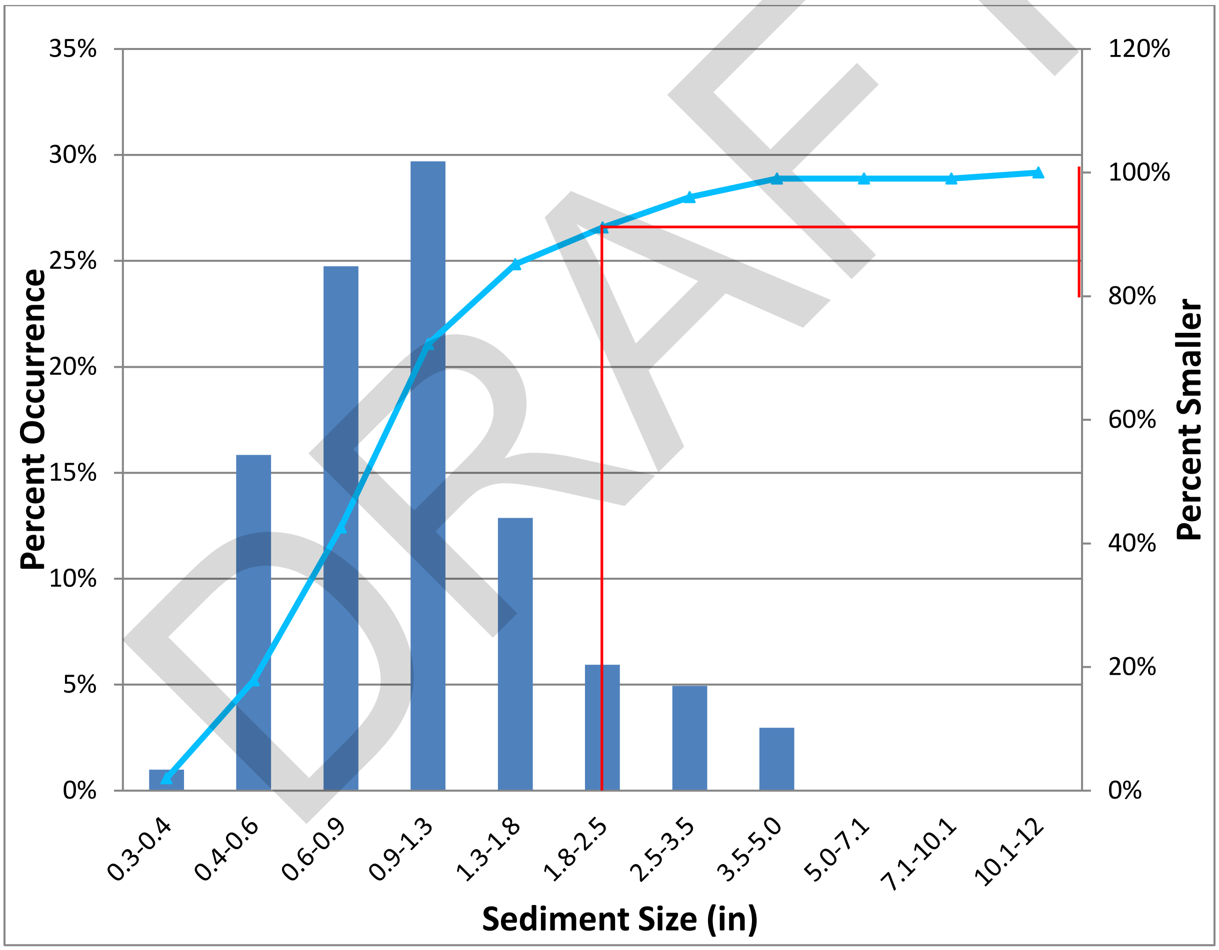

Figure 16 Sediment Properties of Armor Layer

Table 2 Sediment Properties of Armor Layer

	Upstream Diameter (in)
D_{16}	0.6
D_{50}	1.0
D_{84}	1.7
D_{100}	11.9

3.5 Groundwater

The groundwater flow system in WRIA 17 is regionally comprised of a stratified system of aquifers and impervious layers resulting from the westward advance and subsequent eastward retreat of the Vashon continental glacier. From top to bottom, these include: shallow unconfined aquifer, upper confining bed, middle aquifer, lower confining bed, lower aquifer, deeper undifferentiated sediments, and bedrock. On a local scale, these broad regional units have variable occurrence, hydraulic properties, and inter-unit relationships. Aquifers in this system tend to be small and disconnected. Two logged groundwater wells in the project's vicinity provides data on expected groundwater levels that may be encountered during construction. A well located at 3779 W. Sequim Bay Road, located 320 feet northeast of the US 101 project site, discovered a static water level at 31 feet below the surface level. Conversely, another well located at 3830 W. Sequim Bay was drilled to a depth of 520 feet, found no static water level.

4.0 Fish Resources and Site Habitat Assessment

4.1 Fish Use

Table 3 provides a list of native fish potentially found in Discovery Creek and tributaries. Discovery Creek supports the occurrence of coho salmon and coastal cutthroat, as well as other native fish such as sculpin and lamprey. None of these natural populations are species of state or federal concern.

No information is available in regards to fish utilization of this specific stream. However, independent drainages to Discovery Bay and Sequim Bay are recognized as important salmon producers. Limiting factors include natural low flows, logging impacts, and consumptive water diversions.

Table 3 Native Fish Species Potentially Found in Project Vicinity and Upstream:

Species	Source (Assumed, Mapped*, or Documented)	Pre-Existing Fish Use Surveys (spawner surveys or other biological observations)	Life History Present (Egg, Juvenile, Adult)	Limiting Habitat Factors	Stock Status and/or ESA Listing
Coho (Oncorhynchus kisutch)	Assumed	none	Egg, Juvenile, Adult	Spawning and Rearing	Not warranted
Coastal Cutthroat (*Oncorhynchus clarki clarki*)	Mapped	Statewide Integrated Fish Distribution (SWIFD)	Egg, Juvenile, Adult	Spawning and Rearing	Not warranted
Sculpin (*Cottus)*	Assumed	none	Egg, Juvenile, Adult	Spawning and Rearing	Not warranted
Pacific Lamprey (*Lampreta tridentate)*	Assumed	none	Egg, Juvenile, Adult	Spawning and Rearing	Not warranted
Western Brook Lamprey (*Lampreta richardsoni)*	Assumed	none	Egg, Juvenile, Adult	Spawning and Rearing	Not warranted

*Mapped Fish Species Data source: Washington Department of Fish and Wildlife (WDFW)

4.2 Existing Habitat

Discovery Creek and tributaries entering upstream of US 101 offer good spawning and rearing habitat for salmonids. The predominant land use within the watershed includes agricultural/pasture and some forested areas.

4.2.1 Immediate Crossing

The existing culvert is a fish passage barrier due to excessive slope and is undersized for the stream channel. The current conditions result in minimal depth, high velocity flow, and the formation of a water surface drop at the culvert outlet. The proposed fish passage structure will provide fish passage, as well as increased hydraulic capacity, sediment and debris transport.

4.2.2. Quality Within Reach

Downstream of US 101, Discovery Creek flows through mixed coniferous canopy as a pool/riffle complex for a short distance (approximately 252m/823 ft) until it reaches Sequim Bay. Upstream of US 101, the creek flows through a variable landscape with sections of deciduous and coniferous trees and some small areas lacking tree canopy. Stream gradient ranges between 2% and 11%. The channel is generally incised and there are sections of short cascades and several small transient woody debris jams. Riffles and pools provide opportunities for adult salmon spawning and juvenile rearing.

4.2.3 Length of Potential Gain

In April of 2008, WDFW surveyed 3.23 linear miles of potential fish habitat on Discovery Creek and its tributaries upstream of US 101 to the end of potential fish use. WDFW documented 2.84 miles on mainstem Discovery Creek and an additional 0.39 miles on two unnamed tributaries. Due to natural and artificial ponds and pools there is a high proportion of low-velocity, low-gradient flow. Upstream of US 101, Discovery Creek is comprised of an estimated 11% riffle habitat and 89% pool habitat, providing 1,419 square meters (0.35 acres) of spawning habitat and 11,103 square meters (2.74 acres) of rearing habitat.

4.2.4 Other Barriers in System

There are two barriers downstream of the Discovery Creek culvert under US 101. Both are private driveway culverts and are total barriers due to excessive water surface drops (6.7 ft drop and 5.4 ft drop, respectively).Upstream of US 101 there are 18 fish passage barriers. Of the 18 barriers, eight are partial barriers and 10 total barriers. Twelve of the barriers are culverts, 6 are dams. Most of the fish passage barriers are privately-owned, with the exception of three county-owned culverts on public roadway.

4.2.5 Other Restoration Efforts in System

No previous restoration efforts on Discovery Creek are documented in the publicly available data (Figure 17).

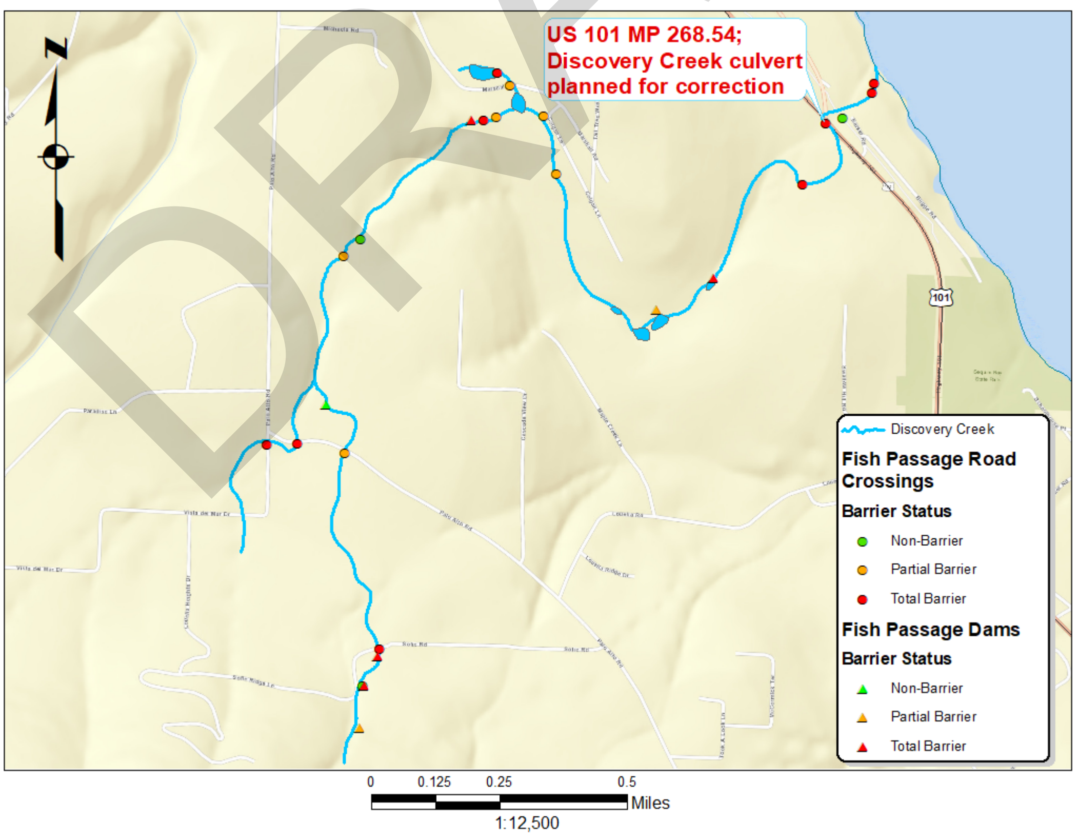

Figure 17 Map of Discovery Creek and tributaries, showing the location of the US 101 stream crossing.

5.0 Reference Reach Selection

The most appropriate reference reach for this project consists of a segment approximately 200 feet upstream of US 101 the culvert (Figure 18). This was deemed to be out of the influence of the culvert and roadway, but representative of streams this size at this position in the landscape. Figure 19 shows photo of this channel segment.

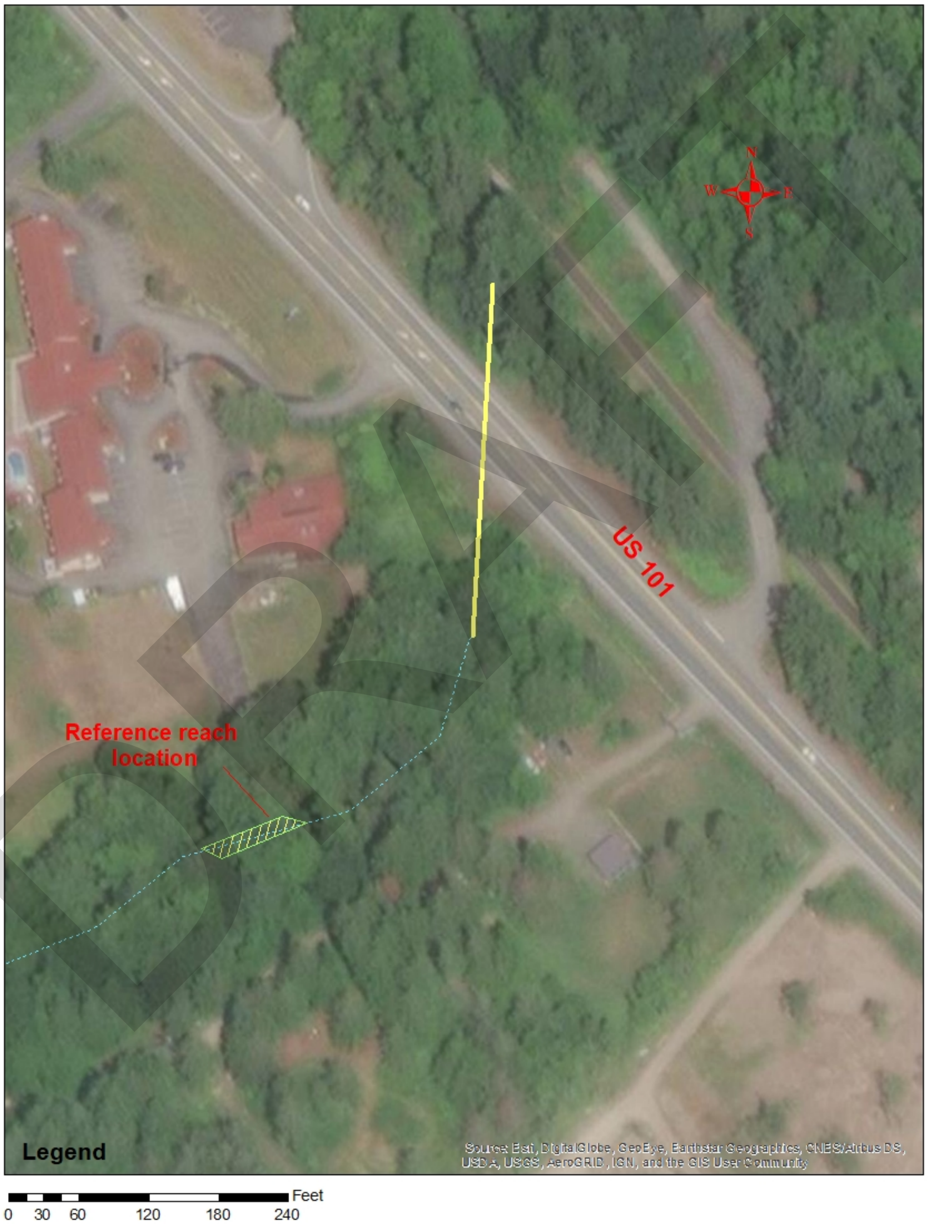

Figure 18 Map showing the location of reference reach for channel design

Figure 19 Image of the Reference Reach Used to Measure BFWs in Discovery Creek

6.0 Hydrology and Peak Flow Estimates

Hydrologic analysis of Discovery Creek is a bit challenging because the input parameters fall outside the applicable limits of all of the methods used. The Discovery Creek watershed drains an area of 1.48 square miles and receives 30.0 inches of mean annual precipitation (MAP) (see Section 3.1). The MAP is below the lower limits of the Region 3 USGS Regression equations. The watershed area is below 50% of the Dean Creek Watershed area therefore, the area ratio method is not technically applicable according to the USGS. Because of the proximity of Dean Creek to Discovery Creek and having similar overall watershed characteristics (geology, land cover), a parallel watershed analysis was chosen to estimate peak flows in Discovery Creek at US 101. Since the flow results from USGS are within a 15% error threshold, therefore it is our best professional judgment to use a more conservative estimate from the USGS flow records as peak flows for the project site (see Table 4).

Table 4 Peak Flows for Discovery Creek

Mean Recurrence Interval (MRI)	Station 12049400 Dean Creek Log Pearson Type III Flows (cfs)	Station 12047100 (3.37 mi^2) Dean Creek Weighted Estimate, Flow/mi^2	Discovery Creek (1.48 mi^2)@ Hwy 101 Area Ratio Estimated Flows (cfs)	Discovery Creek (1.48 mi^2)@ Hwy 101 USGS Region 3 Estimated Flows (cfs)
2	27.2	8.1	12	**16.1**
10	59.7	17.7	26	**33.0**
25	79.7	23.6	35	**42.4**
50	96.1	28.5	42	**49.4**
100	113.6	33.7	50	**57.2**
500	-	-	-	**75.8**

7.0 Hydraulic Analysis

The hydraulic analysis of the existing and the proposed US 101 Discovery Creek crossing was performed using the U.S. Bureau of Reclamation Technical Service Center's Sedimentation and River Hydraulics Two Dimensional River Flow Model (SRH-2D), integrated with Surface-Water Modeling System (SMS) from AquaVeo. SRH-2D, is a two-dimensional (2D) finite-difference, dynamic-flood routing hydraulic model that can simulate channel flow and unconfined overland flow over complex topography with varying roughness. The model uses the full dynamic wave momentum equation and a central finite difference routing scheme with eight potential flow directions to predict the progression of a flood hydrograph over a system of square grid elements. FHWA has contracted with the firm AquaVeo to integrate the SRH-2D model into their Surface-water Modeling System (SMS) which greatly facilitates pre-processing development of the computational mesh elements. SRH-2D has the capability to model hydraulic structures including: bridges, culverts, gates, and weirs. SRH-2D can simulate culvert structures by coupling with the Federal Highway Administrations HY-8 culvert analysis application. A bridge can be modelled by representing it as a pressure flow boundary condition in SMS. In addition, the U.S. Army Corps of Engineers' HEC-RAS computer program, a one-dimensional, gradually varied, steady flow numerical model was also used for comparing the results.

Topographic data used in the modeling analysis was derived from InRoads files supplied by the PEO, which were developed from topographic surveys performed by WSDOT surveyors from the Olympic Region (see Figure 20, 23 and 26).

Three scenarios were analyzed for determining stream characteristics for Discovery Creek with the SRH-2D/SMS models : 1) Natural conditions assuming no structure at the US 101 crossing, 2) existing conditions with the 3-foot diameter culvert and 2) future conditions with the a 17 foot wide hydraulic opening. The proposed 23 foot wide minimum opening (which includes additional width for wildlife connectivity) will be modeled at later phases of the design.

7.1 Natural conditions – No structure at the crossing

The natural condition model and the natural conditions scenarios were developed to evaluate the effect that structure span has on backwater raise, freeboard, velocities through the structure and determine the average flood prone width (FPW) for FUR calculation.

Hydraulic roughness values in the vicinity of the crossing were set based on comparison of site observations to standard text book and engineering manual recommendations for similar conditions. The Manning’s n value for the existing channel upstream and downstream of the project was 0.05. Manning’s n for the existing overbank areas were set to 0.07.

The results in Appendix A, Figure 21 and Figure 22 highlight that no backwater effects are evident to the upstream reach for all modeled peak flows.

The SRH-2D model results confirm that the creek has a FUR value of 1.32 which is less than 3.

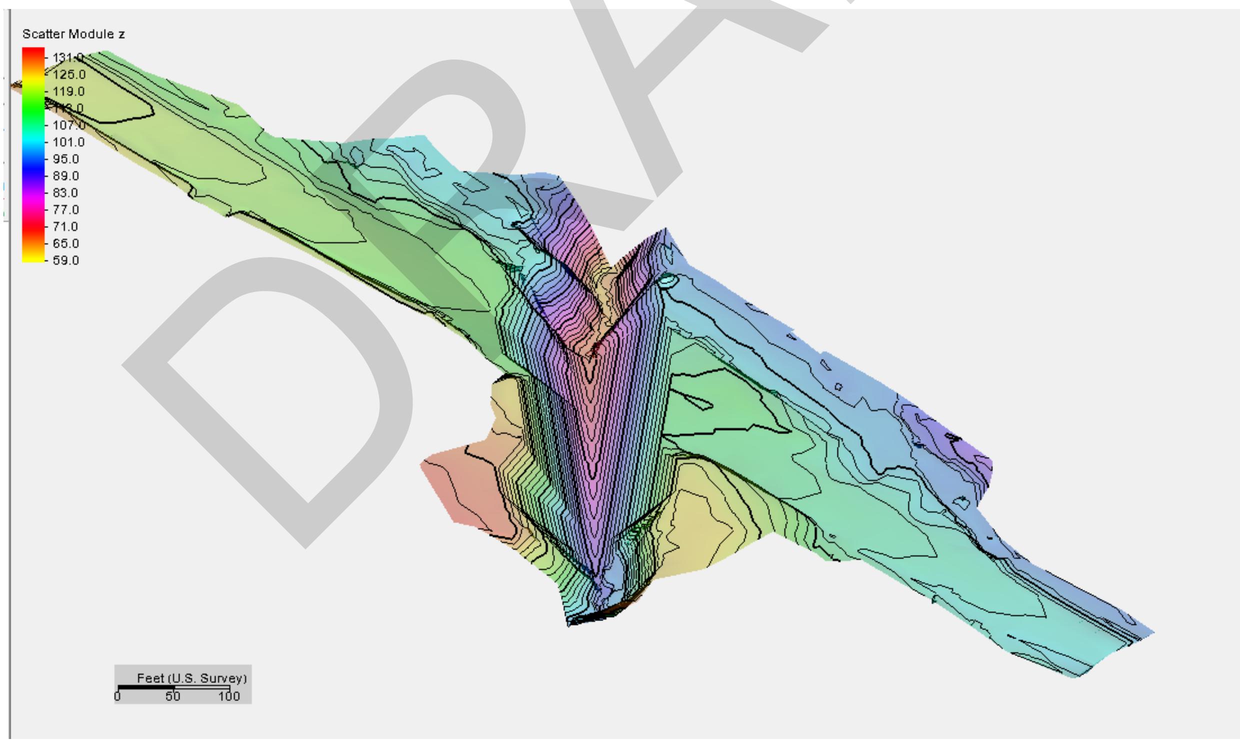

Figure 20 Oblique view of Hypothetical surface created to simulate no structure at US 101 crossing

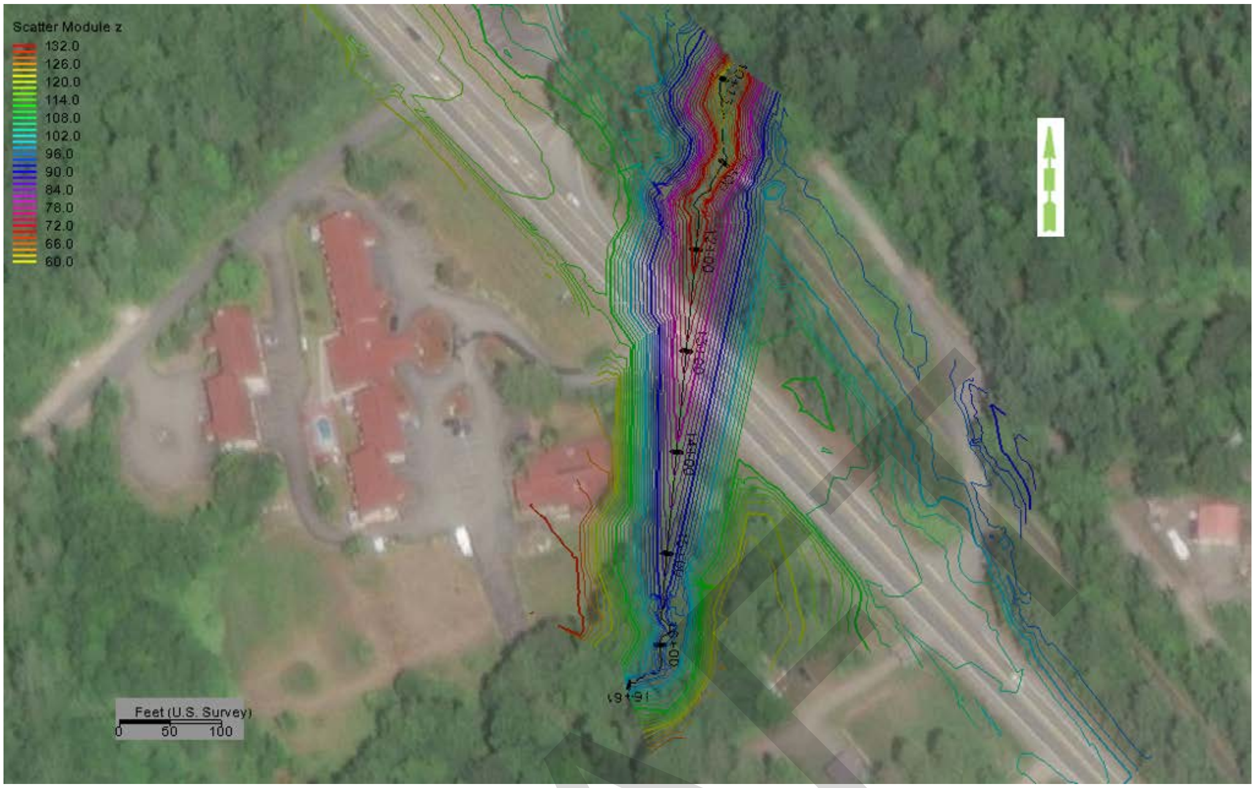

Figure 21 100 year event water surface elevation SRH-2D analysis result plot

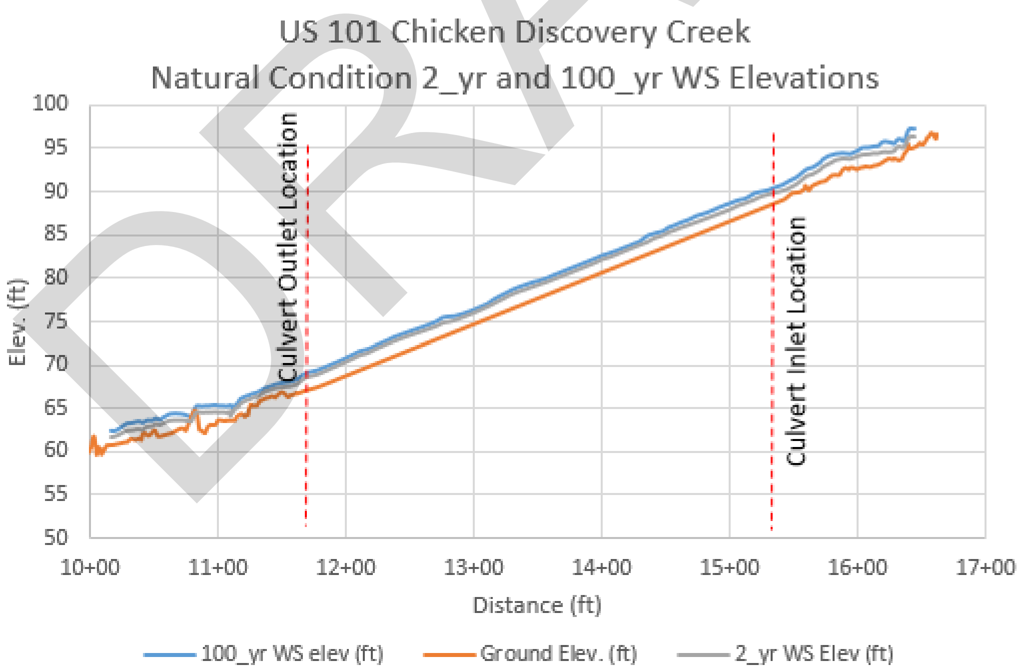

Figure 22 Water surface profile plot of natural condition simulation SRH 2D analysis result

7.2 Existing conditions – 4-Foot/ 3-Foot Diameter Culvert

The existing condition model was created to simulate the existing 4 foot and 3- foot diameter mixed CMP and concrete pipe using project survey data and as-built plans. The 4 foot CMP pipe is embedded by 40 % looking at the culvert inlet. Since, the length of each material type is unknown, for analysis purpose the whole length of the pipe was assumed to be 3-foot concrete pipe. Hydraulic roughness values in the vicinity of the crossing were set based on comparison of site observations to standard text book and engineering manual recommendations for similar conditions. The Manning’s n value for the existing channel upstream and downstream of the project was 0.05. Manning’s n for the existing overbank areas were set to 0.07. A Manning’s n value of 0.024 was used inside of the culvert.

The SRH-2D results confirm that the existing culvert creates excessive outlet velocity conditions at the 2-year and larger peak flows. The roadway will not be overtopped up to the 200-year peak flows. At the existing crossing, the culvert invert flow line and the highway shoulder edge elevations are 88.93 and 112 feet, respectively. The elevations of the 2-, 25-, and 100-year flow events at the upstream face of the existing structure are listed in Table 5.

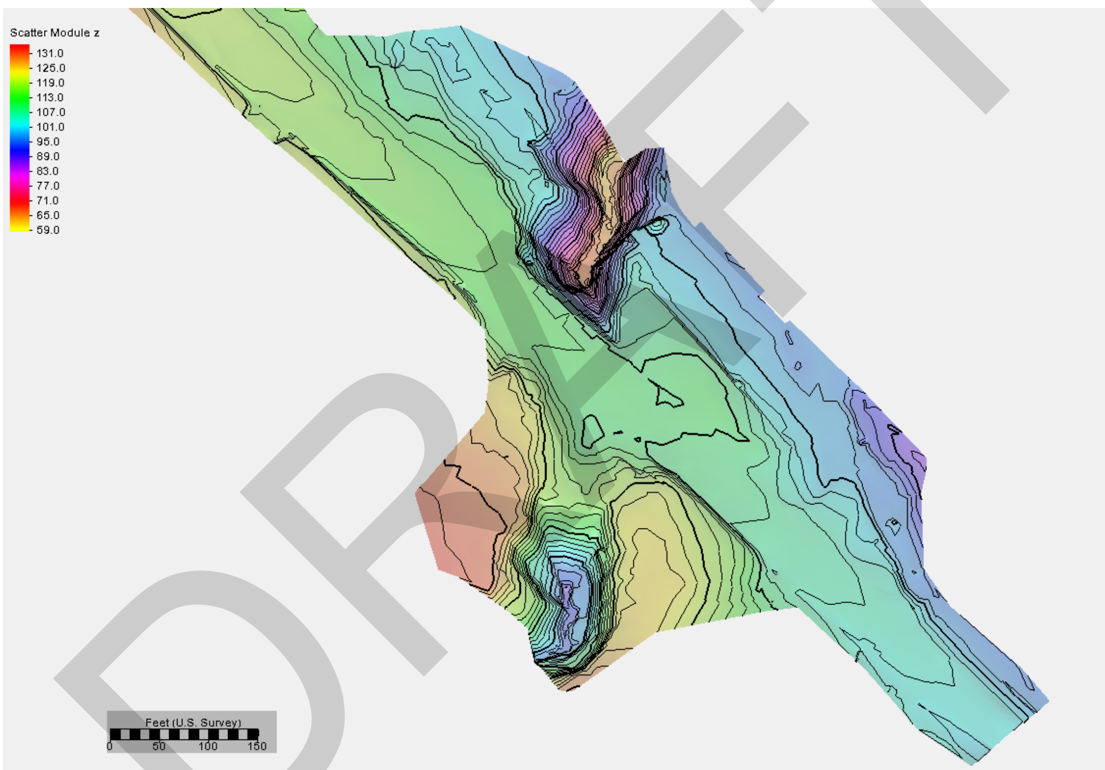

Figure 23 Existing Surface Model used for Existing Culvert SRH-2D Analysis.

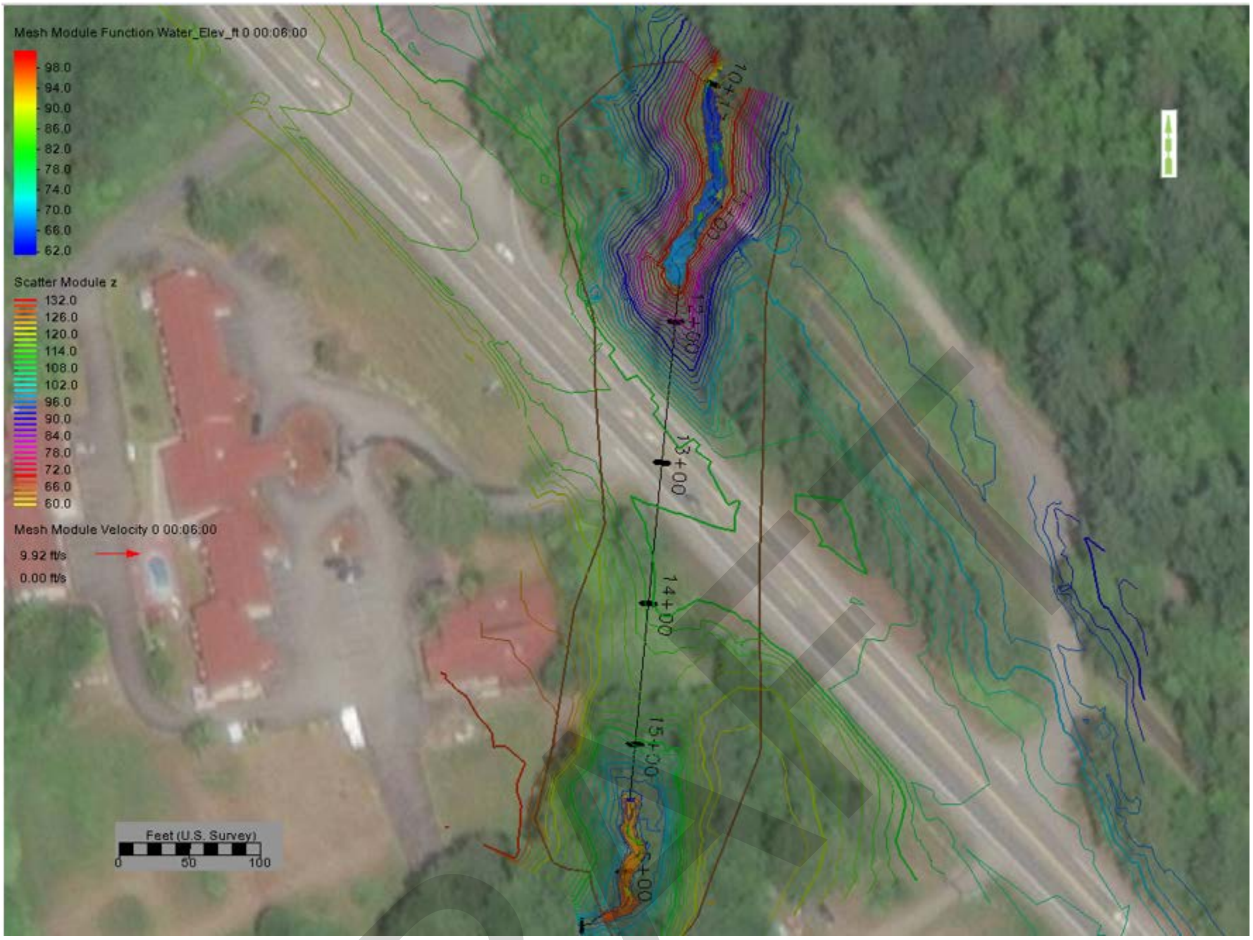

Figure 24 Existing Discovery Creek in the Existing Conditions SRH-2D Model Water surface

Table 5 Water Surface Elevations and Velocities for Existing Conditions

	2-Year Flow	100-Year Flow
WSE at the Existing Inlet (ft)	91.0	97.8
Outlet Velocity (ft/s)	8.1	13.06
Downstream Channel Velocity (ft/s)	4.2	6.0

The results in Appendix A, Figure 24 and Figure 25 highlight that the existing US 101 culvert constricts the flow in the channel and causing backwater effects to the upstream reach for all modeled peak flows higher than 2- year . The outlet velocities are much higher than the downstream velocities (see Table 5). This is supported by the field observation of the undermined culvert and scour pool created at the culvert outlet.

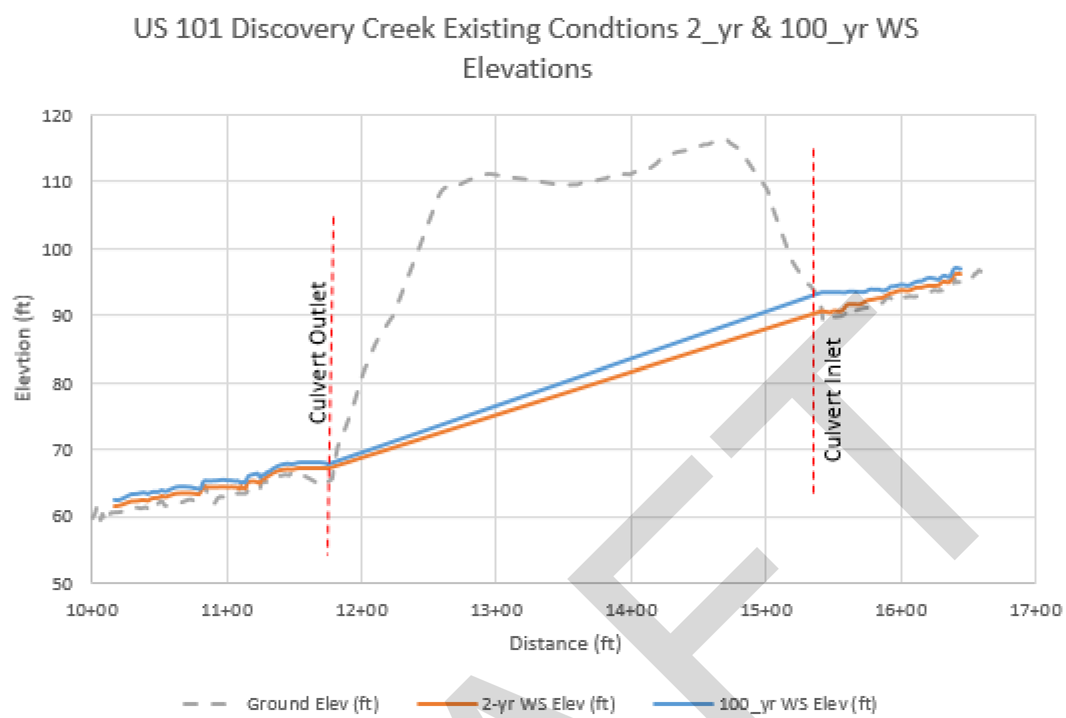

Figure 25 Water Surface Elevation Profile at the Existing US 101 Crossing

7.3 Future conditions –17 Foot Hydraulic Opening

As noted previously in this document, 17 feet is the minimum width for channel processes. An additional 6 feet is being added to allow for 5 foot wide benches above the anticipated 2-year flow event for wildlife connectivity. This section documents the 17 foot wide opening; however the hydraulic model will be updated during later phases of the design to accommodate a minimum 23 foot wide opening.

Hydraulic roughness values in the vicinity of the crossing were set assuming a proposed habitat complexity with LWM and Habitat boulders and based on comparison of site observations to standard text book and engineering manual recommendations for similar conditions. The Manning's n value for the existing channel upstream and downstream of the project was 0.05. Manning's n for the existing overbank areas were set to 0.07. A Manning's n value of 0.06 was used inside the crossing and its vicinity assuming the effect of the proposed habitat complexity.

The SRH-2D model results show a velocity ratio of 0.93; due to the velocity ratio being very near 1 and the confined nature of the system, no additional factor of safety was added to the structure width. Additionally, the results show that no backwater at the proposed crossing at the upstream face of the crossing, the 2-yr and 100-yr water surface elevation are 79.67 and 80.12 feet (NAD 88), respectively. The elevations of the 2-, 25-, and 100-year flow events at the upstream face of the existing structure are listed in Table 6.

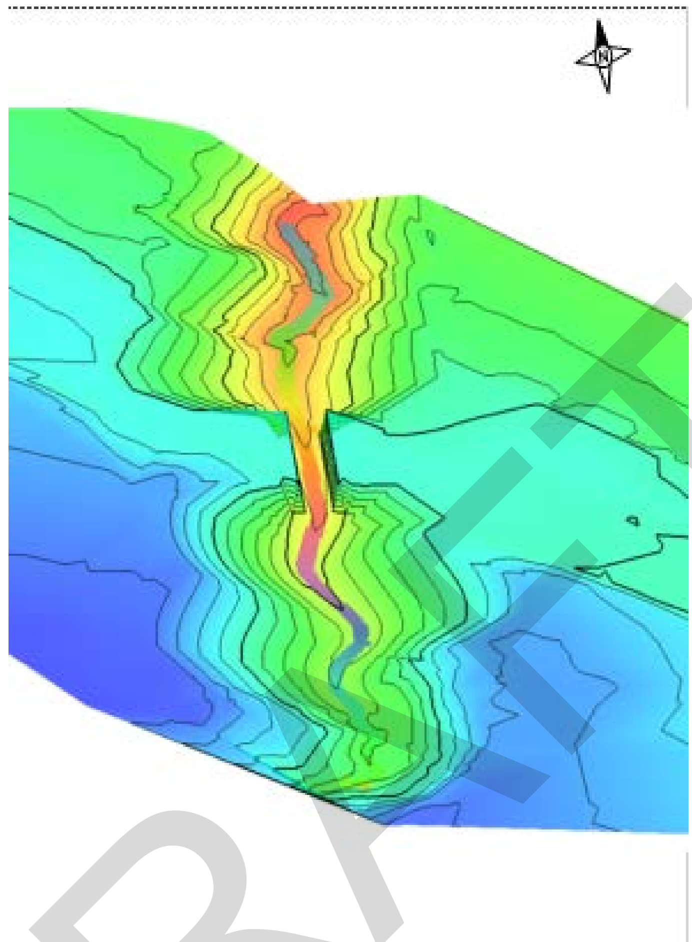

Figure 26 Proposed Discovery Creek in the Proposed Conditions SRH-2D Model Water surface

The proposed conditions velocity distributions for all examined peak flows, provided in Appendix A, indicate that the culvert outlet velocities observed under the existing culvert conditions are reduced. No backwater effects were also observed under all examined peak flows. The average velocities in the constructed channel and through the proposed wider crossing are comparable to the velocity distributions results obtained under natural conditions simulations. The 2-year and 100-year water surface profile plot from the SRH-2D analysis is presented in Figure 27 below. A summary of the water surface elevations, average velocities and average bed shear stress in the channel and through the proposed structure for the 2-year, 100-year and 500-year events are presented in Table 6.

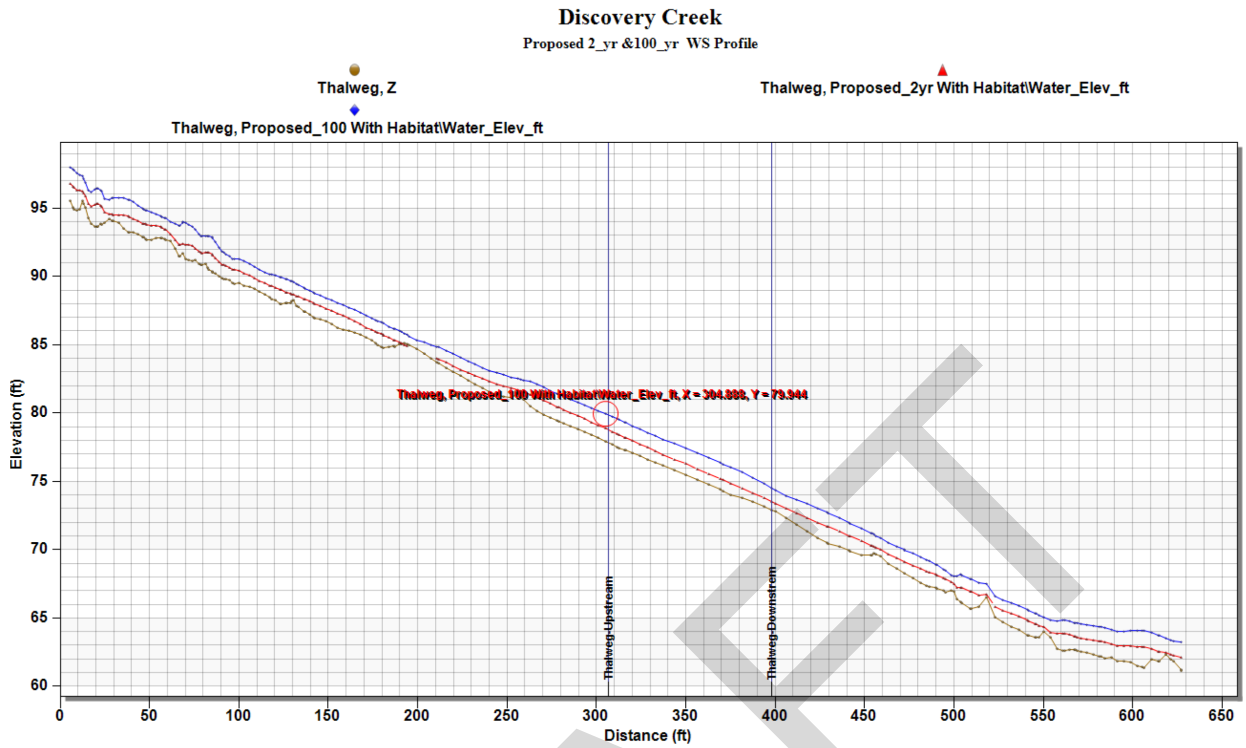

Figure 27 Water Surface Elevation Profile at the Proposed US 101 Crossing

Table 6 Water Surface Elevations and Velocities for Proposed Conditions Upstream US 101 Crossing

Mean Recurrence Interval (MRI)Location	Water Surface Elevation (ft) (NAVD 88)	Average Channel Velocities (ft/s)		Average Velocities (ft/s)	Average Channel Bed Shear Stress (lb/ft.sq.)		Average Bed Shear Stress (lb/ft.sq.)
Location	US	US	DS	inside structure	US	DS	inside structure
2-year	79.41	3.6	2.9	3.07	1.76	1.34	1.38
100- year	80.07	6.20	3.96	3.70	4.33	2.28	2.22
500-year	80.24	6.56	4.43	4.17	4.40	2.86	2.45

8.0 Fish Passage Design Methods Selection

8.1 Design Methodology Selection

The WCDG contain methodology for five different types of crossings: No-Slope Culverts, Stream Simulation Culverts, Bridges, Temporary Culverts or Bridges, and Hydraulic Design Fishways. The permanent federal injunction allows for the use of the stream simulation method and bridge design method unless extraordinary circumstances exist on site. According to the WCDG, a bridge should be considered for a site if the Floodplain Utilization Ratio (FUR) is greater than 3.0, the stream has a bankfull width of greater than 15 feet, the channel is believed to be unstable, the slope ratio exceeds 1.25 between the existing channel and the new channel, or the culvert would be very long. In the case of this crossing, WSDOT opted to use the confined bridge criteria due to fill height and the required length of the structure if a culvert was used. A bridge structure is recommended at this site. .

8.2 Confined Bridge Design Criteria

Streams appropriate for stream simulation design will generally have a FUR of less than three, with some exceptions for low gradient streams with limited potential for meander. The FUR is defined as the flood-prone width (FPW) divided by the bankfull width or 2-year flow width. The FPW is the water surface width at twice the bankfull depth, or the width at the 50-year to 100-year flood.

The creek runs through a deep trench, so there is very limited potential for meander here. This creek has a 1.44 FUR value which is below three when the 2-year water surface width is compared to the 100 year water surface width which is the FPW.

8.2.1 Confined Bridge Design Width

The minimum hydraulic opening for this structure was determined by starting with the stream simulation equation: 1.2 x bankfull width + 2 feet (WCDG Equation 3.2), which gave a minimum width of 17 feet. The velocities were then compared to the adjacent reaches and found to be similar. An additional 6 feet of width will be added to accommodate wildlife. This will yield a factor of safety of 1.9.

The length and type of structure is not yet known at the PHD phase. A bridge structure is recommended at this site if it is practicable to do so due to the height of the fill slope and steepness of the creek. However, given the site constraints described in Section 2, further investigation is needed to determine if a bridge is feasible. If a bridge is not feasible and a buried structure is necessary then the length to width ratio shall not exceed 10.

8.2.2 Backwater and Freeboard

The WCDG recommend the prevention of excessive backwater rise and increased main channel velocities during floods that might lead to scour of the streambed and coarsening of the stream substrate, allow the free passage of debris expected to be encountered, and generally suggests a minimum two foot freeboard for streams of this size. A minimum of 5 feet above the channel thalweg is recommended to perform future maintenance and performing monitoring activity, as well as for the passage of sediment and debris. This results in a total freeboard of approximately 3 feet above the 100-year flow event.

8.2.3 Channel Planform and Shape

The WCDG require that the channel planform and shape mimic conditions within a reference reach. A typical upstream cross section configuration was taken to create the proposed cross section. The proposed cross section will have a low flow channel with a 4:1 side slope for 2.5 feet, followed by a 6.7:1 side slope for 4 feet, followed by 10:1 bench for 5 feet through the structure that is going to be gradually tapered to match the existing upstream channel and downstream channel similar to what is shown in Figure 28; except the 10:1 width will be adjusted to 5 feet to accommodate wildlife.

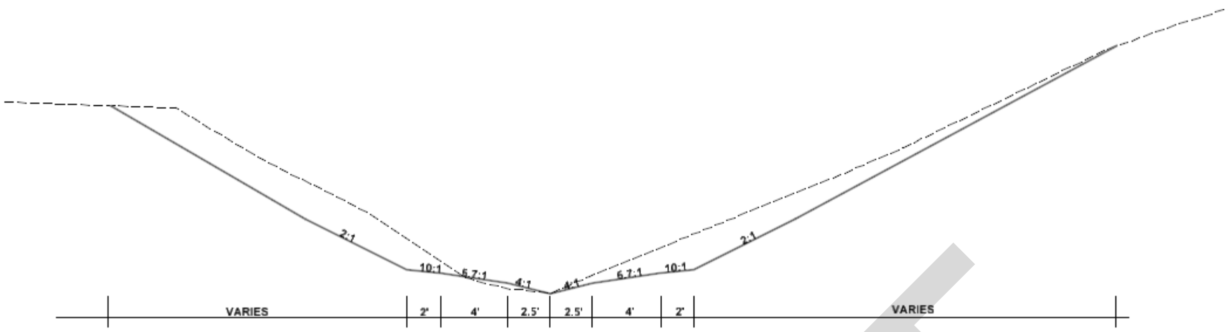

Figure 28 Typical Stream Cross section vs Proposed Cross Section

8.2.4 Floodplain Continuity and Lateral Migration through Structure

The WCDG require that bridges account for lateral channel movement that will occur in their design life and that the design channel maintains floodplain continuity. Since Discovery Creek is confined, lateral migration in the context of the reach is low risk. Lateral migration risk in the context of the structure will need to be evaluated at further stages of the design and may be dependent on structure selected.

8.2.5 Channel Gradient

The WCDG recommend to the extent compatible with safety of the structure, its approach roads, and adjacent private property, to allow natural evolution of the channel planform and longitudinal profile. The proposed structures for this approach 23 feet wide opening placed at 5.57% slope, and if buried structures are proposed, it should be countersunk a minimum of 5 feet (final depths pending final scour analysis). The proposed crossing slope under the proposed crossings creates a slope ratio of 1.02. The slope ratios do not exceed the maximum recommended value of 1.25 for stream simulation. The risk of this degradation will be reduced by the installation of large wood in the restored channel and other channel stabilizing elements, and by restoration of sediment supply from plentiful upstream sources currently disconnected by the existing narrow culvert. This will be addressed in the Final Hydraulic Design Report.

8.2.6 Structure Type

The hydraulic design modeling was performed by assuming a 17 ft wide structure with vertical walls through the entire roadway fill to be certain that the minimum hydraulic opening worked as a worst case scenario. The structure will be widened to 23 feet as a minimum at later stages of the design and remodeled. The roadway fill at this location is very deep and will require a structure length that is very close to the maximum length to width ratio if a buried structure is used. It is also anticipated that long term degradation will have an impact on the structure so a four sided buried structure will need a fair amount of countersink in order to ensure it does not become exposed over time. Maintaining channel structure and fish passage over time may be difficult if a buried structure is used in these circumstances.

As discussed in Section 2.0 and shown in Figure 3, the Sequim Bay Lodge is very close to the existing culvert. Excavating and proving an open cut for a bridge to be installed could require a very large retaining wall in order to prevent an impact to the lodge.

As the design progresses and is evaluated, a bridge should be investigated to determine if it is practicable, as it will give more ability to utilize LWM in channel stabilizing features, as well as allow for vegetation stabilized banks. If a bridge is not practicable, the length of the buried structure should be shortened to the extent practicable utilizing structural shoring and retaining wall structures.

9.0 Streambed Design

9.1 Alignment

The proposed horizontal alignment crosses the road at the same place the existing culvert crosses. The proposed Discovery Creek channel bed through the project area is designed to mimic a natural streambed with a slope of 5.57%.

9.2 Proposed Section

Description of the existing and proposed cross section is presented in Section 8.2.3 above

9.3 Bed Material

Bed material sizing was analyzed using the Bathurst Method, since gradient is steeper than 4%, using flow data from SRH-2D. A spreadsheet for this method developed by WSDOT HQ Hydraulics is included in Appendix B. The flow width and Q within the main portion of the channel was used rather than total flow width or Q. This method indicates that proposed material is stable at the 2-year flow rate inside of the proposed structure. The proposed streambed mix will be constructed using materials described in the WSDOT Standard Specifications, specifically 70% of the Section 9-03.11(1) streambed sediment, and 30% of the Section 9-03.11(2) 12-inch streambed cobble gradations. The subsurface flow will be checked and Streambed Fine Sediment will be applied by force account to meet the intended performance of the bed design.

In addition two and three man boulders will be placed as part of the step-pool configuration as further described in Section 9.4.2 and shown in Appendix C. If habitat elements are used in lieu of a constructed step-pool, then 12 boulders per 100 feet, composed of a combination of one and two man streambed boulders, should be placed as directed by the Engineer. It should be noted that these boulders are not represented in either the Armor Layer Pebble Count or the Proposed Mix Design in Table 7 below; however, boulders are a part of this channel system and should be represented in the final design.

Table 7 Calculated Streambed Gradations for Design Flows

Gradation	Proposed Design mix (in)	Armor Layer (in)	2-yr Diameter (in)	100-yr Diameter (in)
D_{16}	0.1	0.6	0.4	0.7
D_{50}	1.1	1.0	1.4	2.3
D_{84}	5.1	1.7	3.4	5.7
D_{100}	12	11.9	8.6	14.2

9.4 Channel Habitat Features

9.4.1 Large Wood Structures in Discovery Creek

The LWM density will target the 75th percentile of key piece density per Fox and Bolton (2007) and Chapter 10 of the Hydraulics Manual of 3.4 key pieces and 39.48 cubic yards of volume per 100 feet of channel. This percentile of wood placement is suggested to compensate for cumulative deficits of wood loading due to future potential development. Large wood placed within the Discovery Creek channel will be designed to provide habitat-like features, channel complexity, and geomorphic functions similar to those observed in natural wood accumulations. Large wood structures will be installed in Discovery Creek throughout the regraded and day lighted sections of the stream channel. These large wood structures will provide stream complexity, increase channel roughness, create pools, and provide cover in segments that will initially have low natural large wood delivery rates. The large wood will allow new and impacted riparian areas to recover from land-altering construction activities, including the construction of the new culvert and the regrading of the stream channel. The LWM layout will be provided at later stages in the design process as the alignment and structure type are further refined. At the time of this update, a known realignment is being considered so the LWM layout has not been updated using the previous alignment.

All key piece large wood structures will be designed to be stable during an estimated 100-year flood event with a minimum safety factor of 1.5. The techniques used for stabilization have yet to be determined, but will follow the order of preference stated in chapter 10 of the Hydraulic Manual, with no anchors being the highest. If not stable during the design flood, natural and/or mechanical anchors will be incorporated into the design until the required factor of safety is met. Mobile wood will also be considered for this crossing.

9.4.2 Step Pool Configuration

Natural step-pool channels are characterized by an accumulation of cobbles and boulders into transverse bands spanning the channel (Montgomery and Buffington, 1997). The bands result in an alternating series of steps and pools resulting in a stepped longitudinal profile. Step-pool channels are commonly found in steep, coarse-grained mountain streams. In effect, they provide both grade control and instream habitat (Meehan and Bjornn, 1991).

The alternating sequence of supercritical flow (over the steps) and subcritical flow (in the pools) provides energy dissipation (Heede, 1972; Heede, 1981) mainly through the formation of roller eddies

(Hayward, 1978; Hayward, 1980). Under low-flow conditions, each step may be considered as a low-drop, grade-control structure (Abt et al., 1990) with a difference in elevation (H) between the up- and downstream channel beds at a discharge (Q), and a corresponding critical depth (y_C) such that the relative drop height H/y_c, is equal to or less than 1. This technique will require a contractor with experience in step-pool construction.

Step-pool formation requires high discharges and low sediment supply (Ashida et al., 1981; Grant et al., 1990), as well as near-critical to supercritical flow conditions over the bed and must be close to, but not exceed, the entrainment threshold for the larger particles (D_{90} or larger) (Grant and Mizuyama, 1992). Spacing between steps is typically one to four channel widths (Chin, 1989). The spacing decreases with increasing channel slope (Grant et al., 1990) and corresponds to maximum flow resistance (Whittaker and Jaeggi, 1982).

9.4.2.1 Fish Passage and Hydraulics

The stream channel profile grade, whether beneath a bridge structure or through a buried culvert structure, will have a grade of 5.73% along its core 170 ft length. Published studies (Knighton, 1997; Montgomery and Buffington, 1997; Chin, 1999; Chartrand and Whiting, 2000; Zimmerman and Church, 2001; Lee and Ferguson, 2002; MacFarlane and Wohl, 2002) indicate the most efficient hydraulic energy dissipation is a step-pool morphology. The step pool configuration was taken from stable stream patterns observed in the literature. The selected pattern is a primary step followed by a constructed scour pool and a secondary step. Design goals are to make the structure passable 90% of the time and over the widest range of flows, stable over the design life of the stream crossing, most efficient at energy dissipation, and make the structure passable by a wide variety of species and life stages. These hydraulics dissipate energy and provide fish passage through the generation of hydraulic jumps and recirculating currents.

The step height (primary step to primary step) was selected to be 8 inches. The difference between the secondary step and primary step is 6 inches and the step length is 21 feet.

Minimum swimming depth at low flow for this configuration is 12 inches. Residual pool depth at low flow is less than 12 inches, maximum jump height less than 8 inches, and maximum flow velocity of 4 feet per second. Velocity at 8 cfs (about ½ of the 2-year flood and water surface profiles and calculations will be calculated at the design stage).

18 to 19 step-pool structures starting 175 feet at the upstream end of the proposed culvert and ending 50 feet downstream will create passable hydraulics and match the stream elevations. This will need to be verified by a final survey (See Appendix C for step pool conceptual design plans).

Each structure will require 8 or 9 stones 2.5 to 3 feet in diameter for the primary step (not including footer rocks), and 7 to 9 stones 1.5 to 2 feet in diameter for the secondary step.

The bed is designed to be non-mobile. The step-pool design should be modeled at later phases of the design and adjustments made to ensure stability. Coordination will also need to occur with WDFW and interested Tribes to ensure all parties are in agreement with the final bed configuration.

Construction Considerations

Streambed boulders will need to be fit tightly together, adjusting position to minimize gaps between adjacent streambed boulders. Sand and fine gravel will need to be pressure washed into the completed structure to “seal” the rocks and prevent the stream from running underneath the rocks. This will take about 5 to 10 cubic yards of fine material. Careful elevation control will be required when setting the step rocks. Someone with a surveying instrument will need to be on site. The relative elevations are very important to create passable hydraulics.

10.0 Floodplain Changes

There are no flood plain changes either upstream or downstream of the crossing. A small floodplain terrace on the right bank is present south of the proposed regraded channel and should not be affect by the project as it is currently proposed. There are no FEMA jurisdictional floodplains within the project area.

11.0 Climate Resilience

WSDOT recognizes climate resilience as a component of the integrity of its structures and approaches the design of bridges, buried structures, and fish passable structures through a risk based assessment. For bridges and buried structures, a potential to the structures associated with climate change may come from increases in flow and/or sea level rise. The goal of fish passage projects is to maintain natural channel processes through the life of the structure and maintain passability for all expected life stages and species in a system. Therefore, as part of the design process, WSDOT includes evaluating how potential increases in flow and/or sea level rise from climate change could affect fish passability over the life of a structure.

11.1 Climate Resilience Tools

Climate resilience is evaluated at each crossing using the Climate Impacts Vulnerability Assessment Maps created by WSDOT to assess risk level of infrastructure across the state. The Discovery Creek crossing has been evaluated and determined to be a medium risk site based on the Climate Impacts Vulnerability Assessment Maps (Figure 30).

WSDOT also evaluates crossings using the mean percent change in 100-year flood flows from the WDFW Future Projections for Climate-Adapted Culvert Design program. For low or medium risk sites, the 2040 percent increase is used. For high risk sites the 2080 percent increase is used. Appendix E contains the information received from WDFW for this site. The 100-year flow event was chosen to be evaluated, because, as it is an extreme event, if the channel behaves similarly through the structure during this event as it does the adjacent reaches, then it is anticipated this relationship would also be true at lower flows as well.

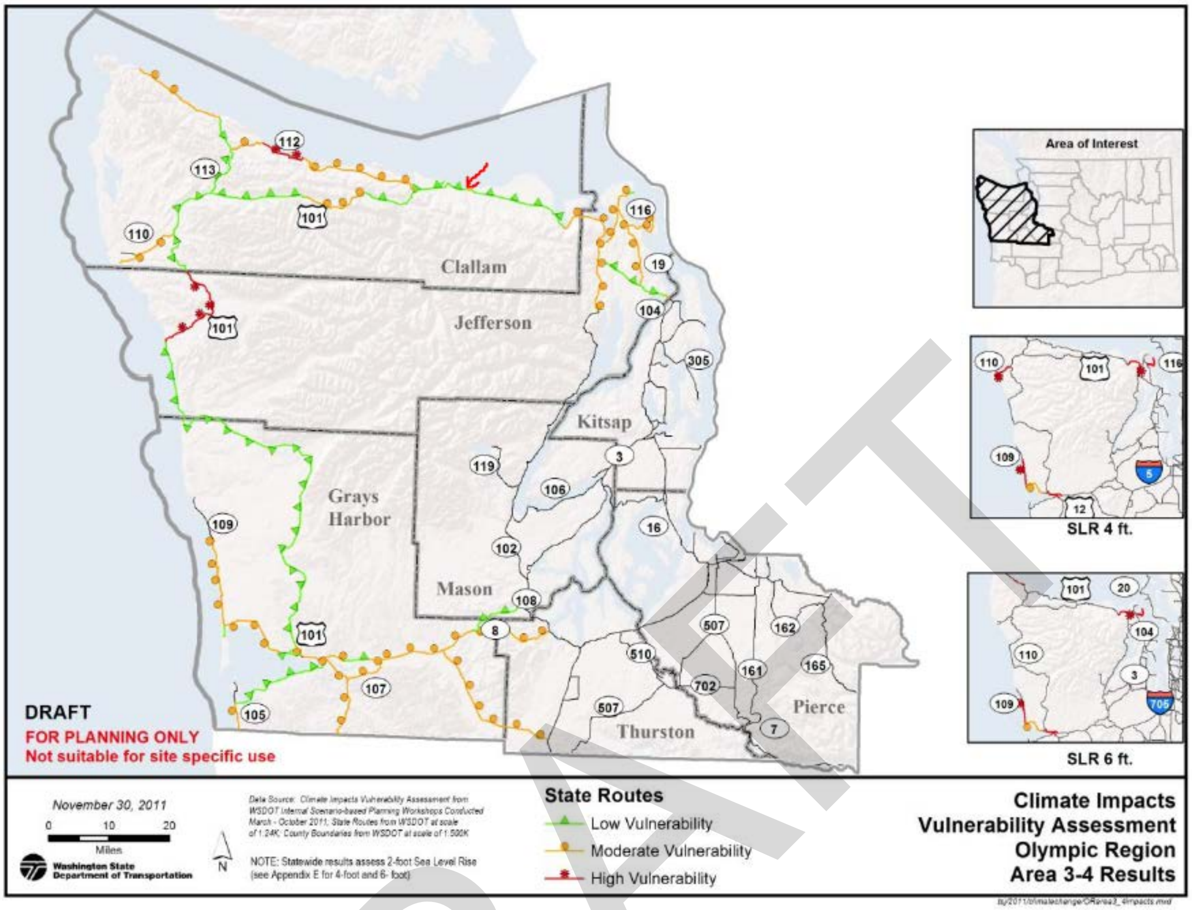

Exhibit B-4.12 Olympic Region – Areas 3 and 4

Figure 29 Climate Impacts Vulnerability Assessment Map

11.2 Hydrology

For each design WSDOT uses, the best available science for assessing site hydrology. The predicted flows are analyzed in the hydraulic model and compared to field and survey indicators, maintenance history, and any other available information. Hydraulic engineering judgement is used to compare model results to system characteristics; if there is significant variation, then the hydrology is re-evaluated to determine whether or not adjustments need to be made, including adding standard error to the regression equation, basin changes in size or use, etc.

In addition to using the best available science for current site hydrology, WSDOT is evaluating the structure at the 2040 projected 100-year flow event to check for climate resiliency. The Design Flow for the crossing 57 cfs at the 100-year storm event. The projected increase for the 2040 flow rate is 16.6%, yielding a projected 2040 flow rate of 66.7 cfs (see Appendix E for climate Change Projections from WDFW). The climate change policy at WSDOT has changed since this PHD was started. The 2080 flow increase is 29.9%, which yields a projected 2080 flow rate of 74.30 cfs. The 500-year projected flow at this crossing is 75.8 and can be used for this project to anticipate what 2080 flows may look like.

11.3 Structure Width

The minimum width for a crossing given by Equation 3.2 was 16.4 feet. The minimum opening width was rounded to 17 feet for conventional construction purposes. The width will be increased an additional 6 feet to 23 feet to accommodate wildlife; however, the model has not yet been updated to reflect this. The 17 structure width was evaluated at the 100-year flow event, projected 2040 100-year flow event, and 500-year flow event and determined to produce less than 10% increase in velocities through the structure and upstream reaches. The increase in velocities does not warrant an increase in structure width. The velocity comparisons for these flow rates can be seen in Table 8 below.

Table 8 Velocity Comparison for 17 Foot Hydraulic Opening

	100-Year Velocity (ft/s)	Projected 100-Year Velocity (ft/s)	500-Year Velocity (ft/s)
Upstream of Structure	**6.20**	**6.2**	**6.56**
Through Structure	**3.70**	**3.97**	**4.17**
Downstream of Structure	**3.96**	**4.19**	**4.44**

11.4 Freeboard and Countersink

The minimum recommended freeboard at this location based on bankfull width was 2 feet at the 100-year flow event. The water surface elevation is projected to increase by 0.1 feet for the 2040 projected 100-year flow rate and 0.3 feet for the 500-year flow rate. The minimum freeboard at this site was increased from 2 feet to 3 feet at this site to allow for additional height for constructability, maintenance, and monitoring. This additional height will also accommodate projected climate change impacts.

No additional freeboard depth was added to the structure because of the low risk of aggradation and an insignificant increase in water surface elevation bringing the minimum height required to 8 foot structure if a four sided structure is proposed. The structure will be designed to account for the potential scour at the projected 2080 100-year flow events.

11.4 Summary

A minimum hydraulic opening of 17 feet and a minimum freeboard of 3 feet allows for the channel to behave similarly through the structure as it does in the adjacent reaches under the projected 2040 100-year flow event and the 500-year event. An additional factor of safety is added in through the width increase for wildlife connectivity, increasing the minimum span from 17 feet to 23 feet. This will help ensure that the structure is resilient to climate change and the system is allowed to function naturally, including the passage of sediment, debris and water in the future.

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Appendices

Appendix A – SRH-2D Model Results

Appendix B – Streambed Material Sizing Calculations

Appendix C – Step Pool Conceptual Design Plans

Appendix D – Stream Plan Sheets, Profile, Details

Appendix E—WDFW Future Projections for Climate-Adapted Culvert Design Printout

Appendix F – Long Profile From LiDAR data

Appendix A – SRH-2D Model Results

Model has not been updated to reflect updated structure size or updated alignment

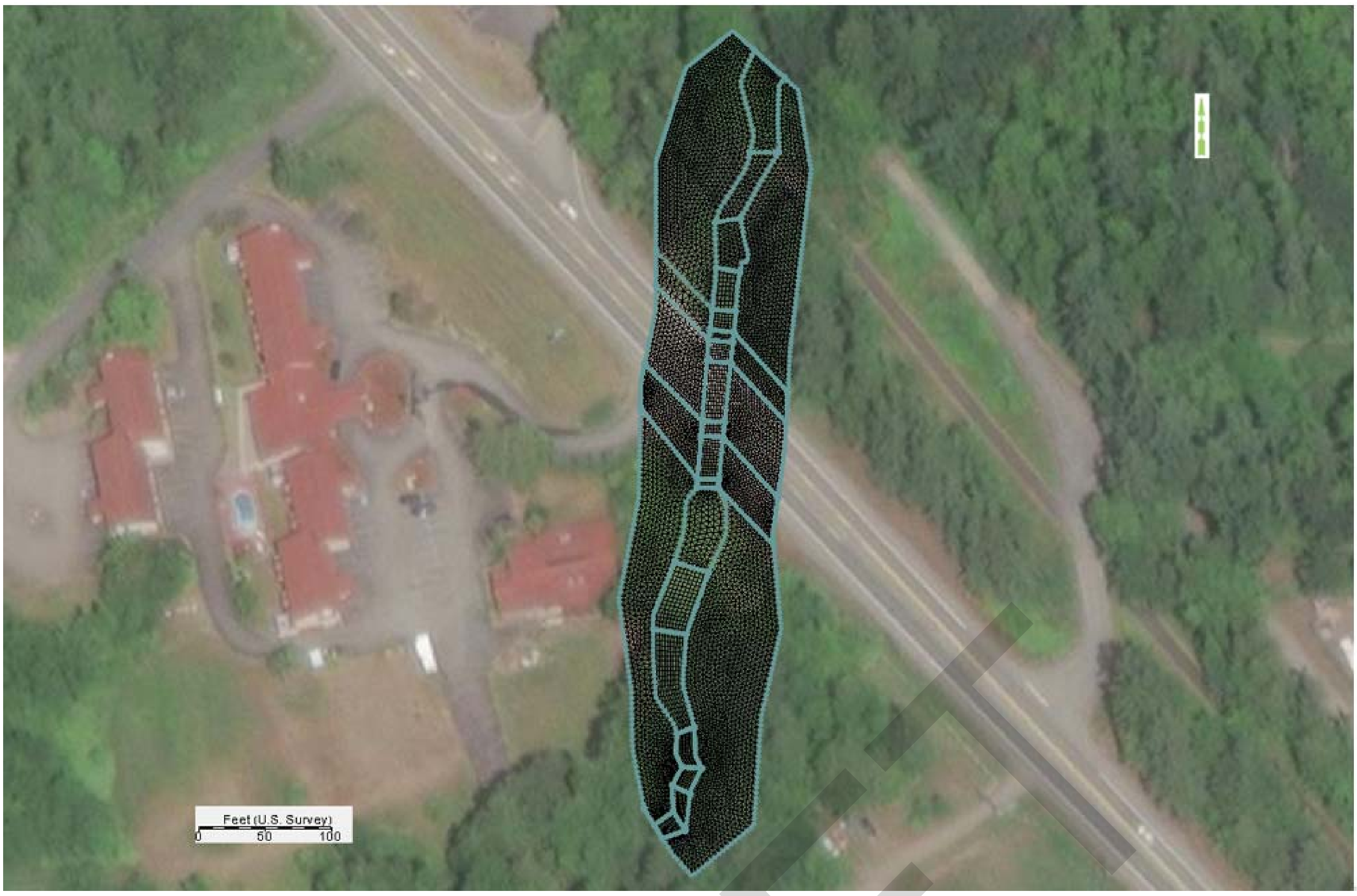

Figure A1 US 101 Discovery Creek SMS Mesh Area and inlet and outlet Boundary Conditions set up under Proposed Conditions Simulation

Figure A2 US 101 Discovery Creek 2-yr Velocity Magnitude under Proposed Conditions Simulation

Figure A3 US 101 Discovery Creek 100-yr Velocity Magnitude under Proposed Conditions Simulation

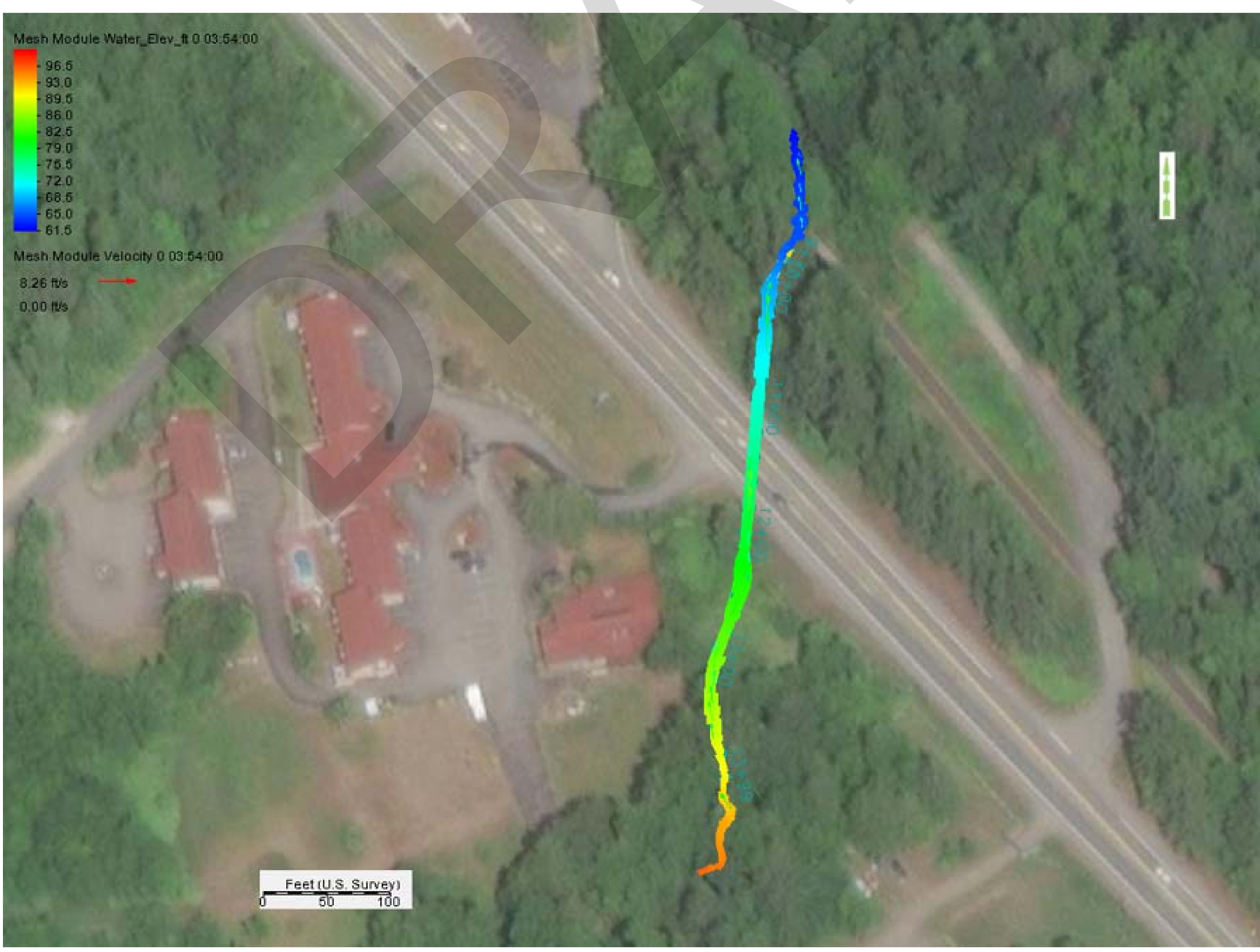

Figure A4 US 101 Discovery Creek 2-yr Water Surface Elevation under Proposed Conditions Simulation

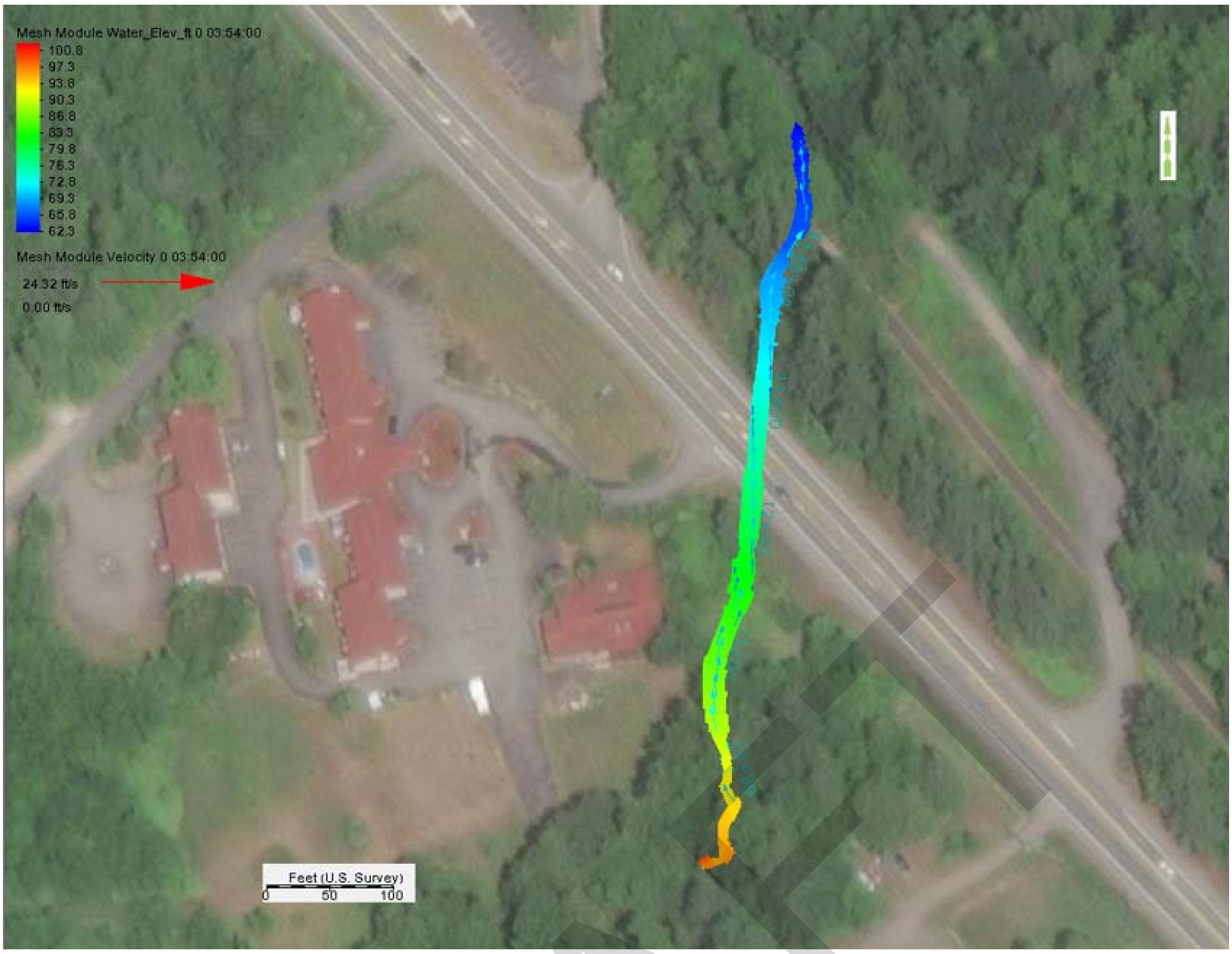

Figure A5 US 101 Discovery Creek 100-yr Water Surface Elevation under Proposed Conditions Simulation

Figure A6 US 101 Discovery Creek 2-yr Bed Shear Stress under Proposed Conditions Simulation

Figure A7 US 101 Discovery Creek 100-yr Bed Shear Stress under Proposed Conditions Simulation

Appendix B – Streambed Material Sizing Calculations

Washington State Department of Transportation

BED MATERIAL SIZING CALCULATIONS

Project:	US 101 Discovery Creek		
SR Route:		**Mile Post:**	268.54
Stream Crossing:	Scatter Creek		
Designer:	Y. Bereded-Samuel	**Date:**	9/24/2019
Checked By:	H.Pittman		

References:

Bathurst, J.C. (1987) Critical Conditions for Movement in Steep Boulder-Bed Streams. Int. Assoc. of Hydraulical Sciences Pub. Vol. 165.

$$D_{84} = 3.45 * S^{0.747} * \frac{(1.25 * q_c)^{\frac{2}{3}}}{g^{\frac{1}{3}}}$$

$$cfs = \frac{ft^3}{s}$$

<u>Input Data From HEC-RAS</u>

Cross Section Name/Station:			
Flow Event:		*2*	yr
Energy Slope (S) - ft/ft:	S =	*0.057*	ft/ft
100-yr Flow in Main Channel (Q):	Q =	*16.1*	cfs
Stream Width (W):	W =	*6.0*	ft
Specific Discharge (q_c) - (cfs/ft):	q_c =	*2.7*	ft^2/s

$$q_c = \frac{Q}{W}$$

$$D_{84} = 3.45 * S^{0.747} * \frac{(1.25 * q_c)^{\frac{2}{3}}}{g^{\frac{1}{3}}}$$

D_{84} =	0.29	ft
	3.44	in

$$D_{16} = \frac{D_{84}}{8}$$

D_{16} =	0.04	ft
	0.43	in

$$D_{50} = \frac{D_{84}}{2.5}$$

D_{50} =	0.11	ft
	1.38	in

$$D_{100} = \frac{D_{84}}{0.4}$$

D_{100} =	0.72	ft
	8.61	in

Washington State Department of Transportation

BED MATERIAL SIZING CALCULATIONS

Project:	US 101 Discovery Creek		
SR Route:		**Mile Post:**	268.54
Stream Crossing:	Scatter Creek		
Designer:	Y. Bereded-Samuel	**Date:**	9/24/2019
Checked By:	H.Pittman		

References:

Bathurst, J.C. (1987) Critical Conditions for Movement in Steep Boulder-Bed Streams. Int. Assoc. of Hydraulical Sciences Pub. Vol. 165.

$$D_{84} = 3.45 * S^{0.747} * \frac{(1.25 * q_c)^{\frac{2}{3}}}{g^{\frac{1}{3}}}$$

$$cfs = \frac{ft^3}{s}$$

Input Data From HEC-RAS

Cross Section Name/Station:			
Flow Event:		*100*	yr
Energy Slope (S) - ft/ft:	S =	*0.057*	ft/ft
Flow in Main Channel (Q):	Q =	*57.2*	cfs
Stream Width (W):	W =	*10.0*	ft
Specific Discharge (q_c) - (cfs/ft):	q_c =	*5.7*	ft^2/s

$$q_c = \frac{Q}{W}$$

$$D_{84} = 3.45 * S^{0.747} * \frac{(1.25 * q_c)^{\frac{2}{3}}}{g^{\frac{1}{3}}}$$

D_{84} = 0.48 ft
5.71 in

$$D_{16} = \frac{D_{84}}{8}$$

D_{16} = 0.06 ft
0.71 in

$$D_{50} = \frac{D_{84}}{2.5}$$

D_{50} = 0.19 ft
2.28 in

$$D_{100} = \frac{D_{84}}{0.4}$$

D_{100} = 1.19 ft
14.26 in

Washington State Department of Transportation

BED MATERIAL SIZING CALCULATIONS

Project:	US 101 Discovery Creek		
SR Route:		**Mile Post:**	268.54
Stream Crossing:	Scatter Creek		
Designer:	Y. Bereded-Samuel	**Date:**	9/24/2019
Checked By:	H.Pittman		

References:

Bathurst, J.C. (1987) Critical Conditions for Movement in Steep Boulder-Bed Streams. Int. Assoc. of Hydraulical Sciences Pub. Vol. 165.

$$D_{84} = 3.45 * S^{0.747} * \frac{(1.25 * q_c)^{\frac{2}{3}}}{g^{\frac{1}{3}}}$$

$$cfs = \frac{ft^3}{s}$$

Input Data From HEC-RAS

Cross Section Name/Station:			
Flow Event:		*500*	yr
Energy Slope (S) - ft/ft:	S =	*0.057*	ft/ft
Flow in Main Channel (Q):	Q =	*75.8*	cfs
Stream Width (W):	W =	*10.0*	ft
Specific Discharge (q_c) - (cfs/ft):	q_c =	*7.6*	ft^2/s

$$q_c = \frac{Q}{W}$$

$$D_{84} = 3.45 * S^{0.747} * \frac{(1.25 * q_c)^{\frac{2}{3}}}{g^{\frac{1}{3}}}$$

D_{84} = 0.57 ft
6.88 in

$$D_{16} = \frac{D_{84}}{8}$$

D_{16} = 0.07 ft
0.86 in

$$D_{50} = \frac{D_{84}}{2.5}$$

D_{50} = 0.23 ft
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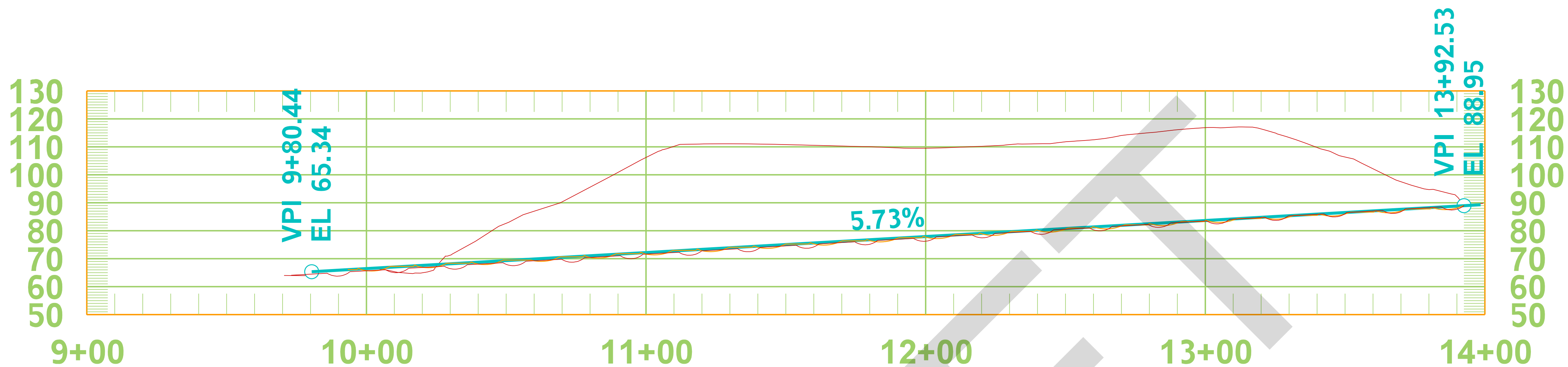
$$D_{100} = \frac{D_{84}}{0.4}$$

D_{100} = 1.43 ft
17.21 in

Appendix C – Step Pool Conceptual Design Plans



US 101 DISCOVERY CREEK CROSSING CONCEPTUAL STEP POOL CONFIGURATION

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DESIGNED BY	Y.Bereded-Samuel			
ENTERED BY	Y.Bereded-Samuel			
CHECKED BY				
PROJ. ENGR.				
REGIONAL ADM.		REVISION	DATE	BY

REGION NO.	STATE	FED.AID PROJ.NO.
10	WASH	
JOB NUMBER		
CONTRACT NO.		LOCATION NO.

DATE
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DATE
P.E. STAMP BOX

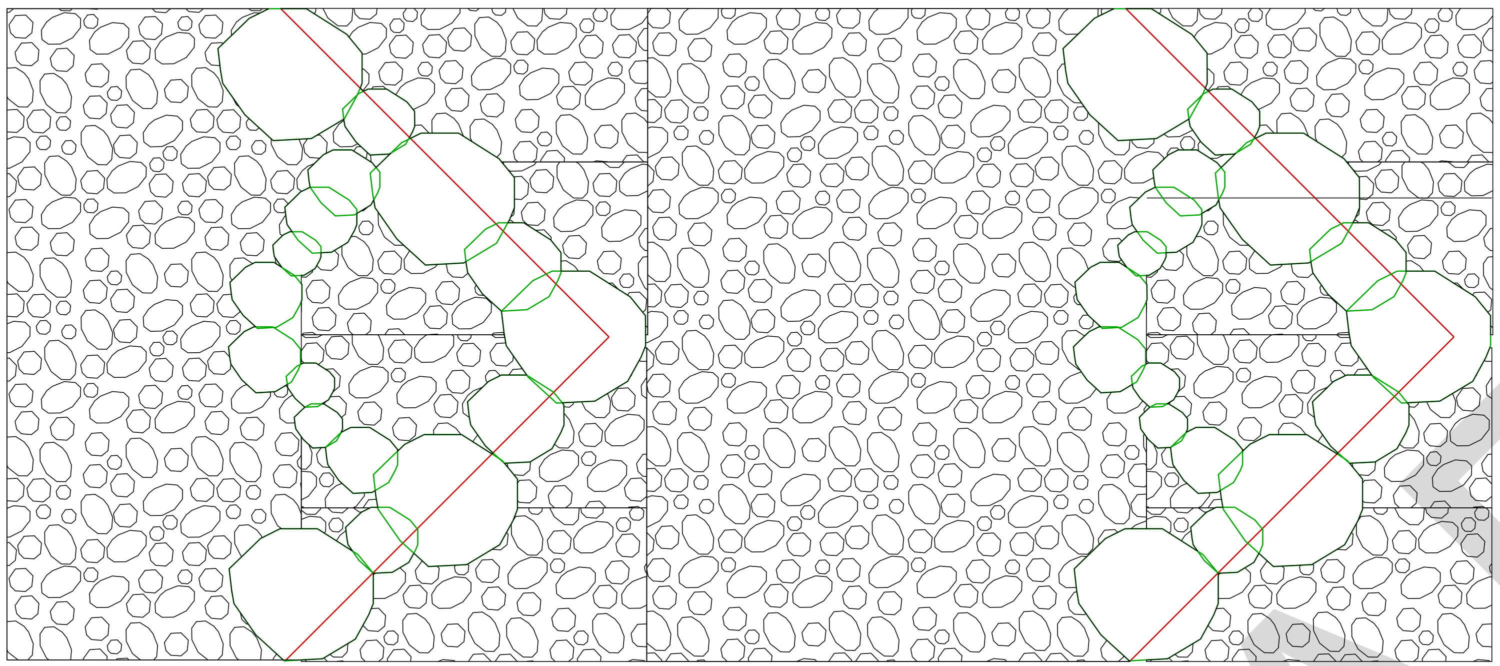
Washington State
Department of Transportation

US 101
US 101 Discovery Creek
US 101 DISCOVERY CREEK
Step Pool Conceptual Plan
FISH PASSAGE

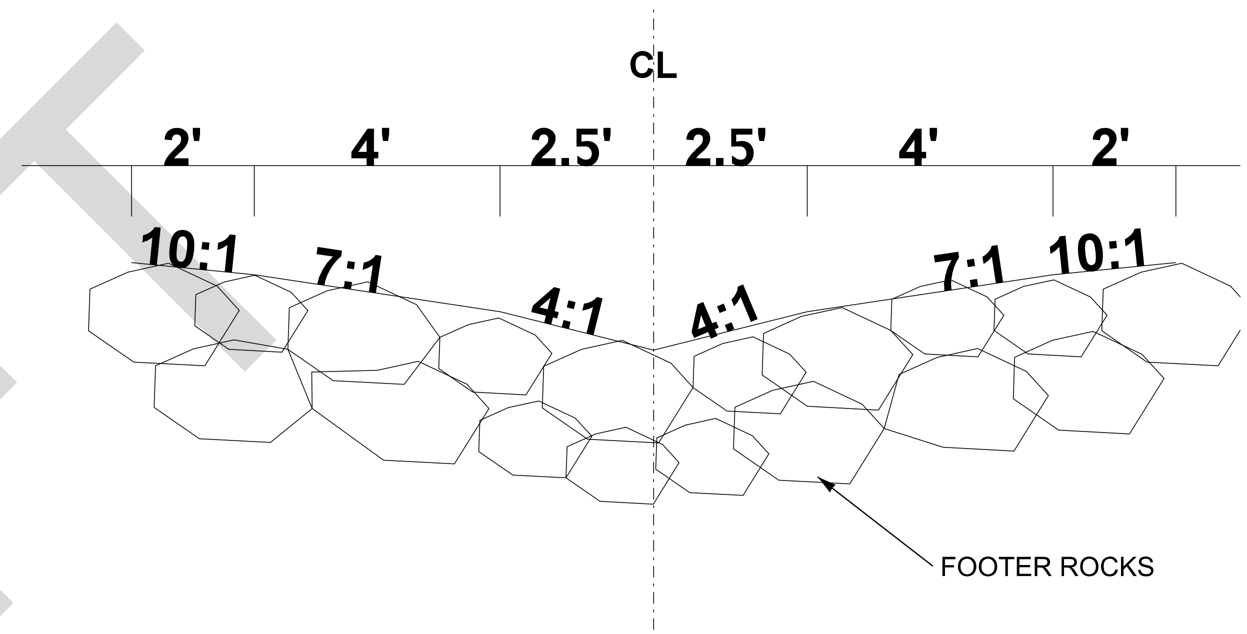
STEP POOL CONFIGURATIONS

Plot 1
PLAN REF NO
SHEET
OF
SHEETS

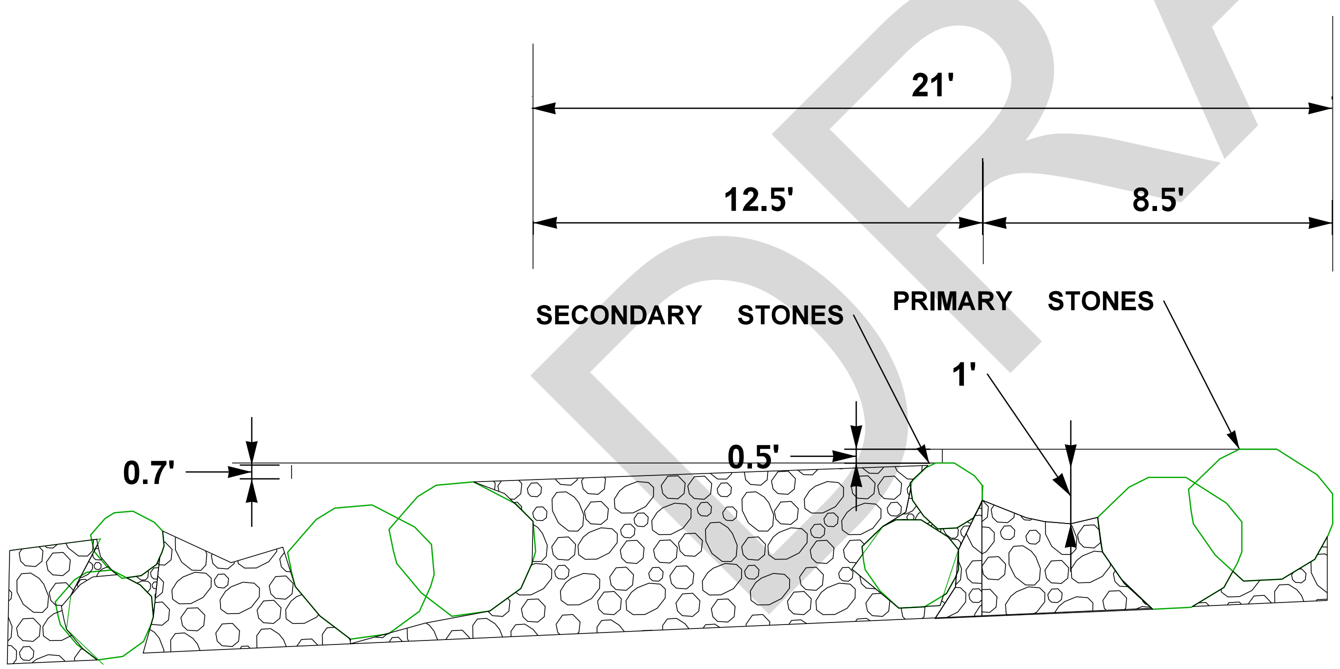
45 degree



TYPICAL STEP POOL CONFIGURATIONS PLAN VIEW



TYPICAL CROS SECTION



TYPICAL STEP POOL CONFIGURATIONS PROFILE VIEW

NOTES:

1. THE PRIMARY STONES ARE 24" TO 36" IN DIAMETER WITH STREAMBED MATERIAL.
2. THE SECONDARY STONES ARE 18" TO 24" WITH STREAMBED MATERIAL INTERFIL
3. THE POOL IS FILLED WITH STREAMBED FILLED
4. AFTER ALL STEPS AND POOLS HAVE BEEN PLACED, THE ENTIRE STRUCTURE WILL BE PRESSURE WASHED WITH FINE MATERIAL TO SEAL THE STRUCTURE.
5. POOL DEPTH WAS DESIGN AT 12"

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Washington State Department of Transportation

US 101

US 101 Discovery Creek DISCOVERY CREEK

Step Pool Conceptual Plan FISH PASSAGE

STEP POOL DETAILS

Plot 2

PLAN REF NO

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OF

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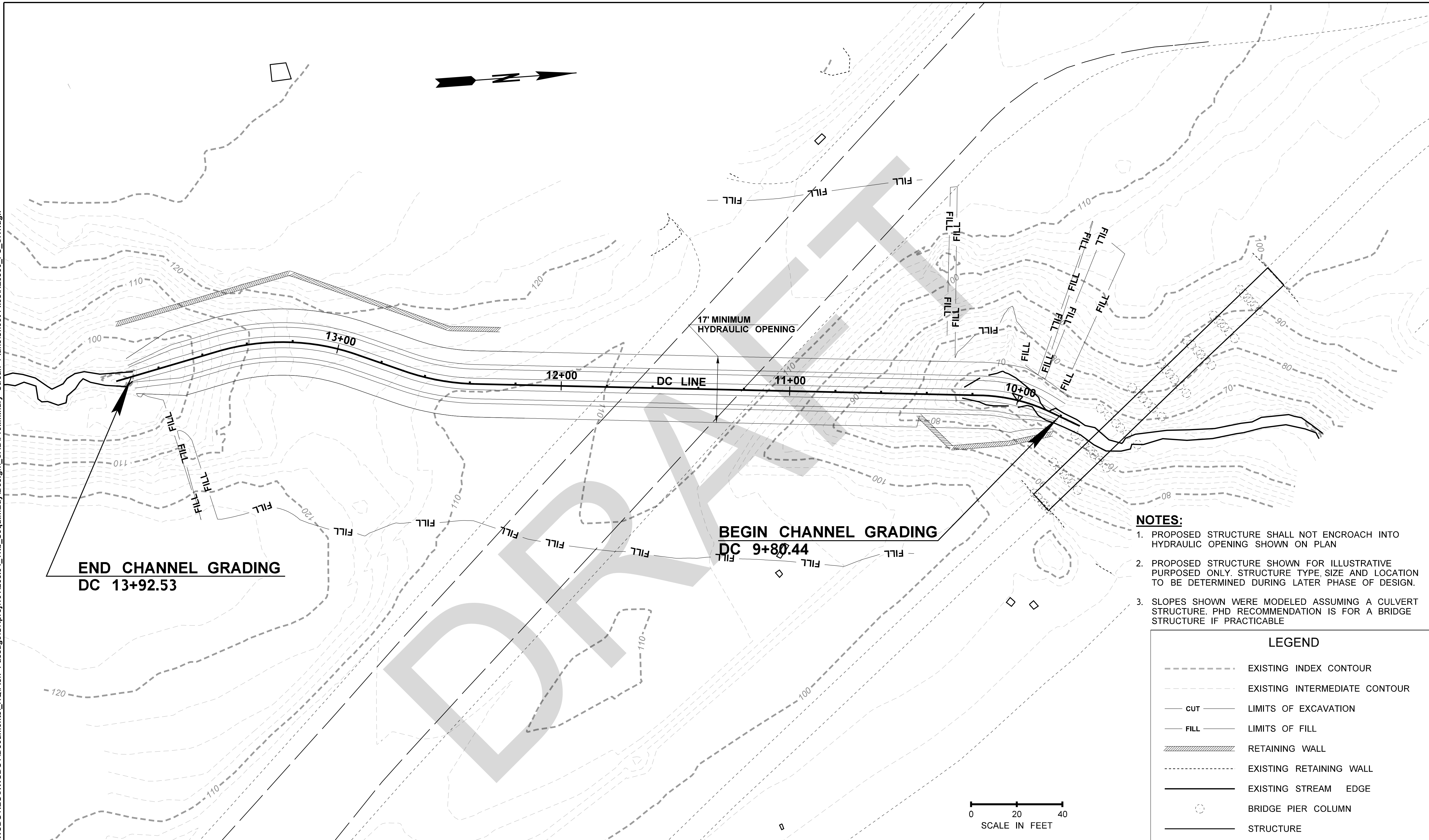
Appendix D – Stream Plan Sheets, Profile, Details

Plans have not been updated to reflect updated structure size or alignment



NOTES:

1. PROPOSED STRUCTURE SHALL NOT ENCROACH INTO HYDRAULIC OPENING SHOWN ON PLAN
2. PROPOSED STRUCTURE SHOWN FOR ILLUSTRATIVE PURPOSED ONLY. STRUCTURE TYPE, SIZE AND LOCATION TO BE DETERMINED DURING LATER PHASE OF DESIGN.
3. SLOPES SHOWN WERE MODELED ASSUMING A CULVERT STRUCTURE. PHD RECOMMENDATION IS FOR A BRIDGE STRUCTURE IF PRACTICABLE

LEGEND

	EXISTING INDEX CONTOUR
	EXISTING INTERMEDIATE CONTOUR
CUT	LIMITS OF EXCAVATION
FILL	LIMITS OF FILL
	RETAINING WALL
	EXISTING RETAINING WALL
	EXISTING STREAM EDGE
	BRIDGE PIER COLUMN
	STRUCTURE

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ENTERED BY	P. DANA
CHECKED BY	Y. BEREDED-SAMUEL
PROJ. ENGR.	J. METTLER
REGIONAL ADM.	J. WYNANDS

REVISION	DATE	BY

REGION NO.	STATE	FED.AID PROJ.NO.
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CONTRACT NO.		LOCATION NO.

P.E. STAMP BOX DATE

P.E. STAMP BOX DATE

Washington State
Department of Transportation

US101
UNNAMED TRIB. TO DISCOVERY BAY
REMOVE FISH PASSAGE

STREAM PLAN

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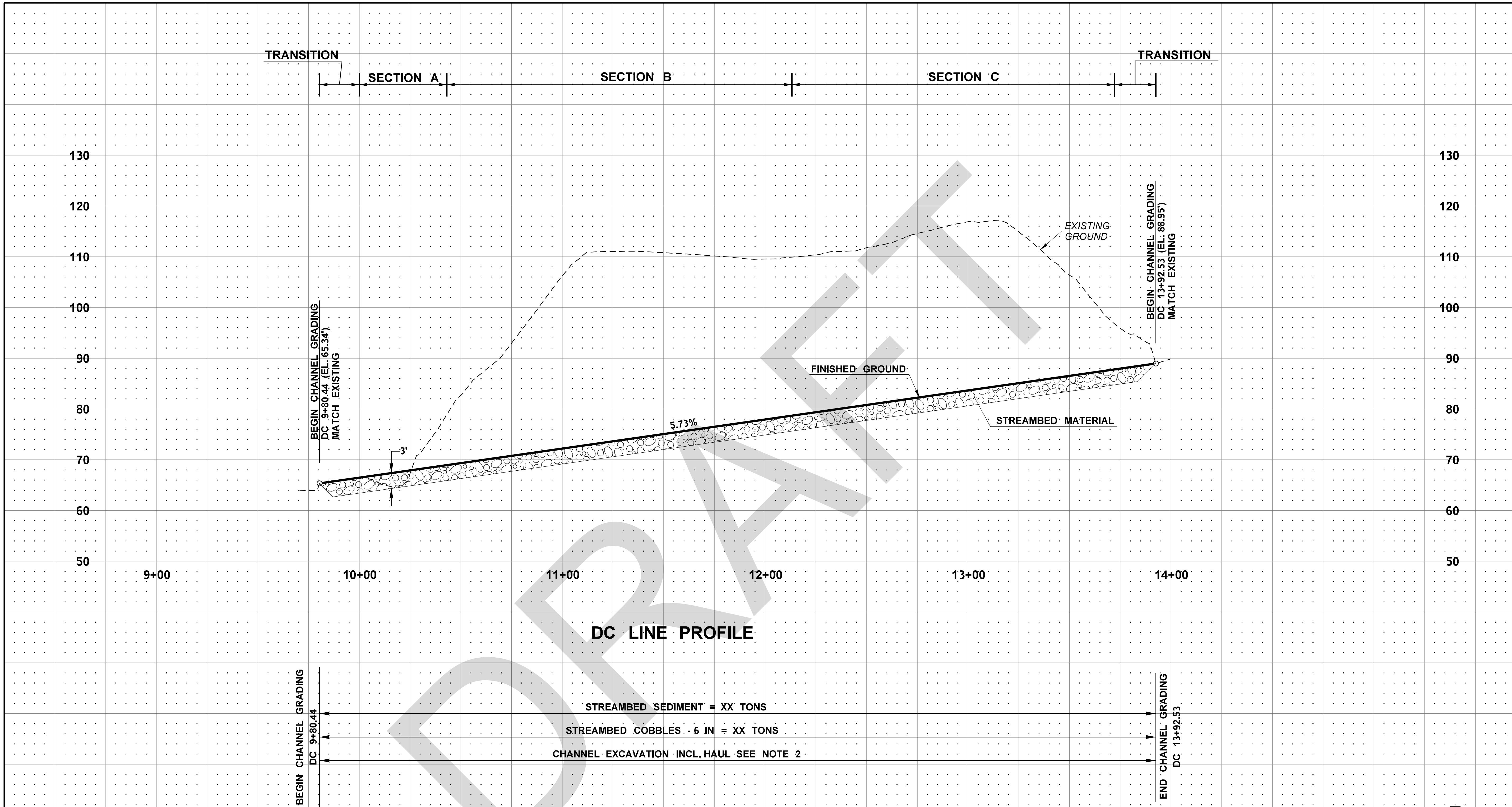

NOTES:

1. SEE SPECIAL PROVISIONS "AGGREGATES FOR STREAMS, RIVERS, AND WATERBODIES" FOR STREAMBED MATERIAL. FINAL INSTALLATION SHALL PROVIDE A WELL GRADED MIX OF STREAMBED SEDIMENTS AND STREAMBED COBBLES.
2. SEE SPECIAL PROVISIONS "EARTHWORK" FOR CONSTRUCTION REQUIREMENTS AND APPROXIMATE QUANTITIES.

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PROJ. ENGR.	J. METTLER
REGIONAL ADM.	J. WYNANDS

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CONTRACT NO. | LOCATION NO.

P.E. STAMP BOX DATE

P.E. STAMP BOX DATE

Washington State Department of Transportation

US101
UNNAMED TRIB. TO DISCOVERY BAY
REMOVE FISH PASSAGE

STREAM PROFILE

PLAN REF. NO. CP1

SHEET OF SHEETS

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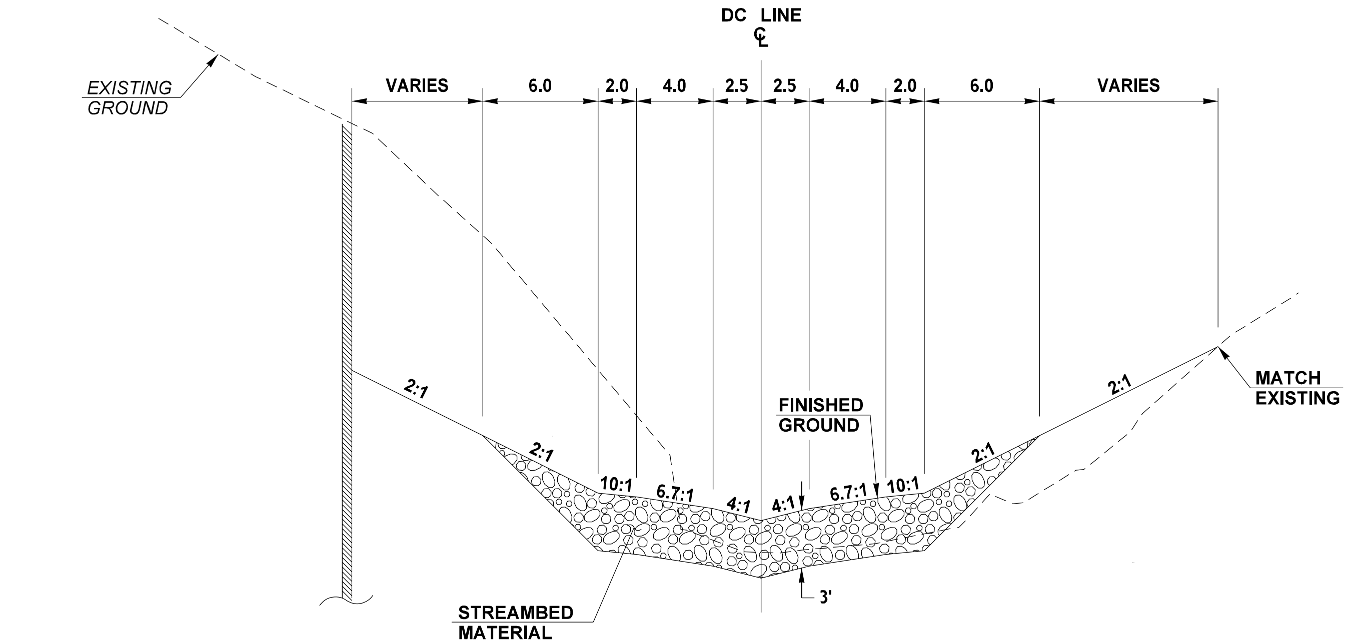
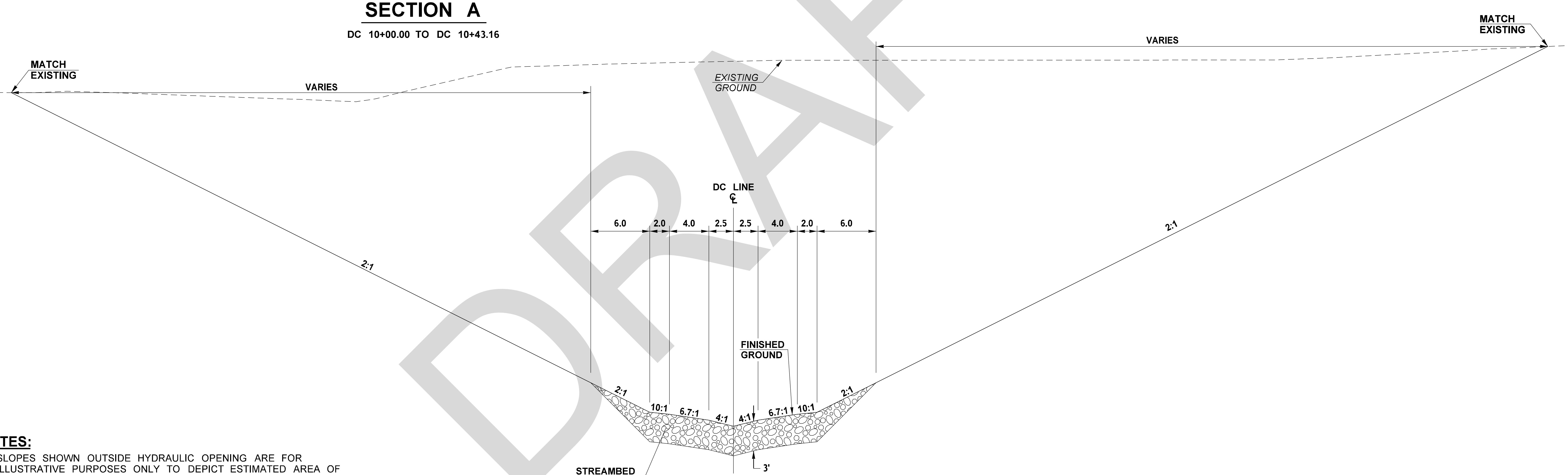


SECTION A

DC 10+00.00 TO DC 10+43.16



SECTION B

DC 10+43.16 TO DC 12+13.16

NOTES:

1. SLOPES SHOWN OUTSIDE HYDRAULIC OPENING ARE FOR ILLUSTRATIVE PURPOSES ONLY TO DEPICT ESTIMATED AREA OF POTENTIAL IMPACT. FINAL AREAS OF IMPACT TO BE DETERMNED PENDING GEOLOGICAL AND STRUCTURAL INVESTIGATION, STRUCTURE TYPE AND STRUCTURE LOCATION.

2. PROPOSED STRUCTURE SHALL NOT ENCROACH INTO MINIMUM OPENING SHOWN ON PLAN.

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PROJ. ENGR.	J. METTLER			
REGIONAL ADM.	J. WYNANDS	REVISION	DATE	BY

REGION NO.	STATE	FED.AID PROJ.NO.
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Washington State
Department of Transportation

US101
UNNAMED TRIB. TO DISCOVERY BAY
REMOVE FISH PASSAGE

STREAM DETAILS

PLAN REF NO
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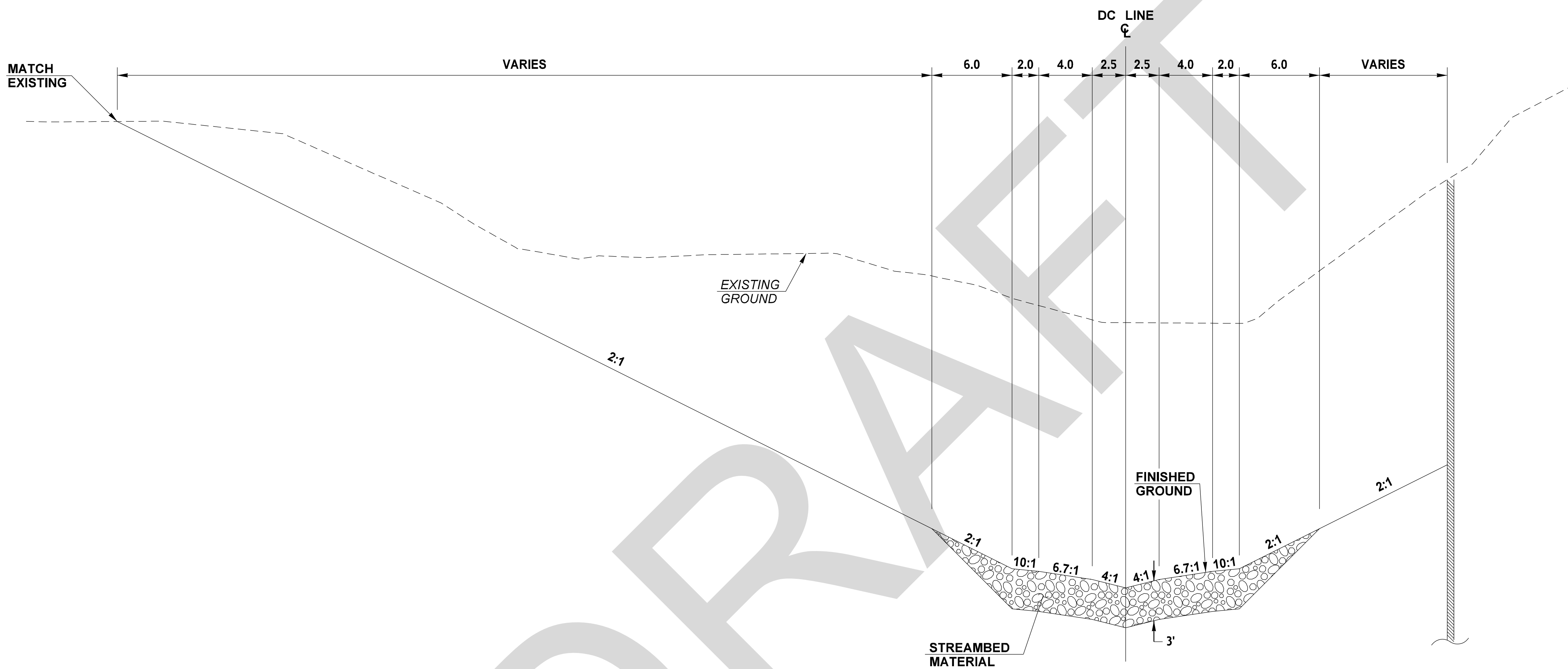

SECTION C

DC 12+13.16 TO DC 13+72.16

NOTES:

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2. PROPOSED STRUCTURE SHALL NOT ENCROACH INTO MINIMUM OPENING SHOWN ON PLAN.

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REGIONAL ADM.	J. WYNANDS

REVISION	DATE	BY

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P.E. STAMP BOX DATE

P.E. STAMP BOX DATE

Washington State
Department of Transportation

US101
UNNAMED TRIB. TO DISCOVERY BAY
REMOVE FISH PASSAGE

STREAM DETAILS

PLAN REF NO
CD2

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OF
SHEETS

Appendix E – Future Climate Projections from WDFW

Future Projections for Climate-Adapted Culvert Design

Project Name: 991667

Stream Name:

Drainage Area: 176 ac

Projected mean percent change in bankfull flow:

2040s: 12.3%

2080s: 16.5%

Projected mean percent change in bankfull width:

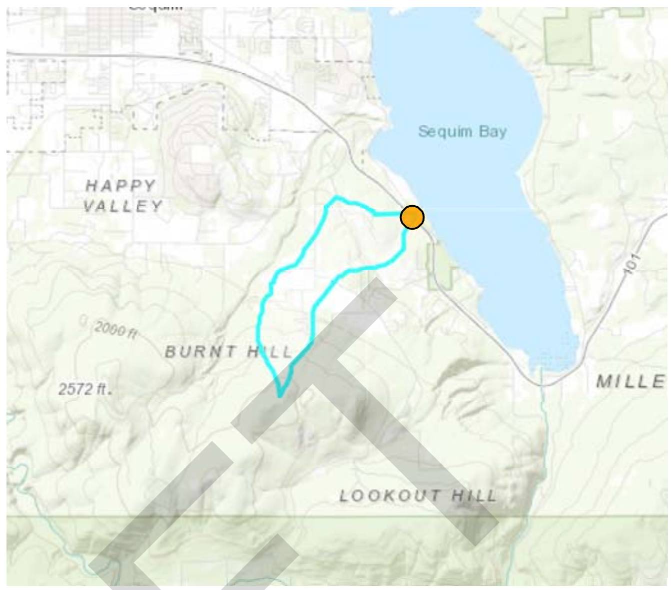
2040s: 6%

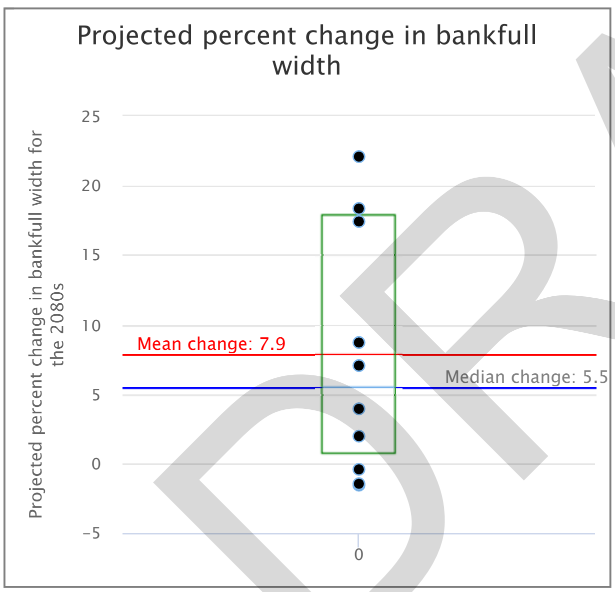
2080s: 7.9%

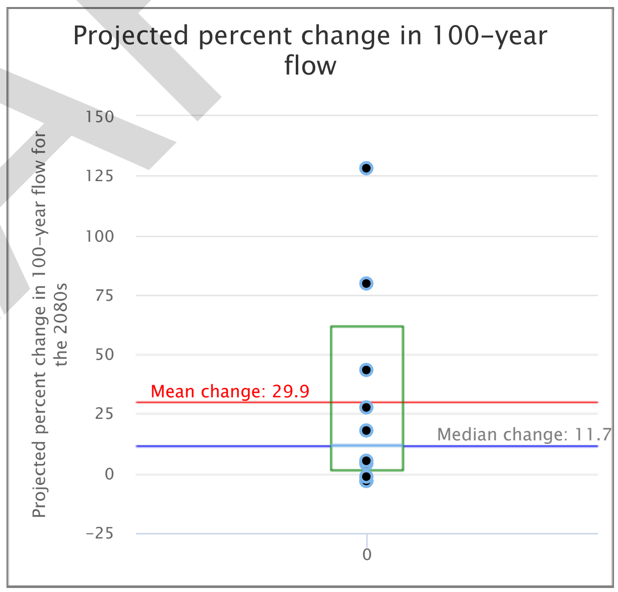
Projected mean percent change in 100-year flood:

2040s: 16.6%

2080s: 29.9%

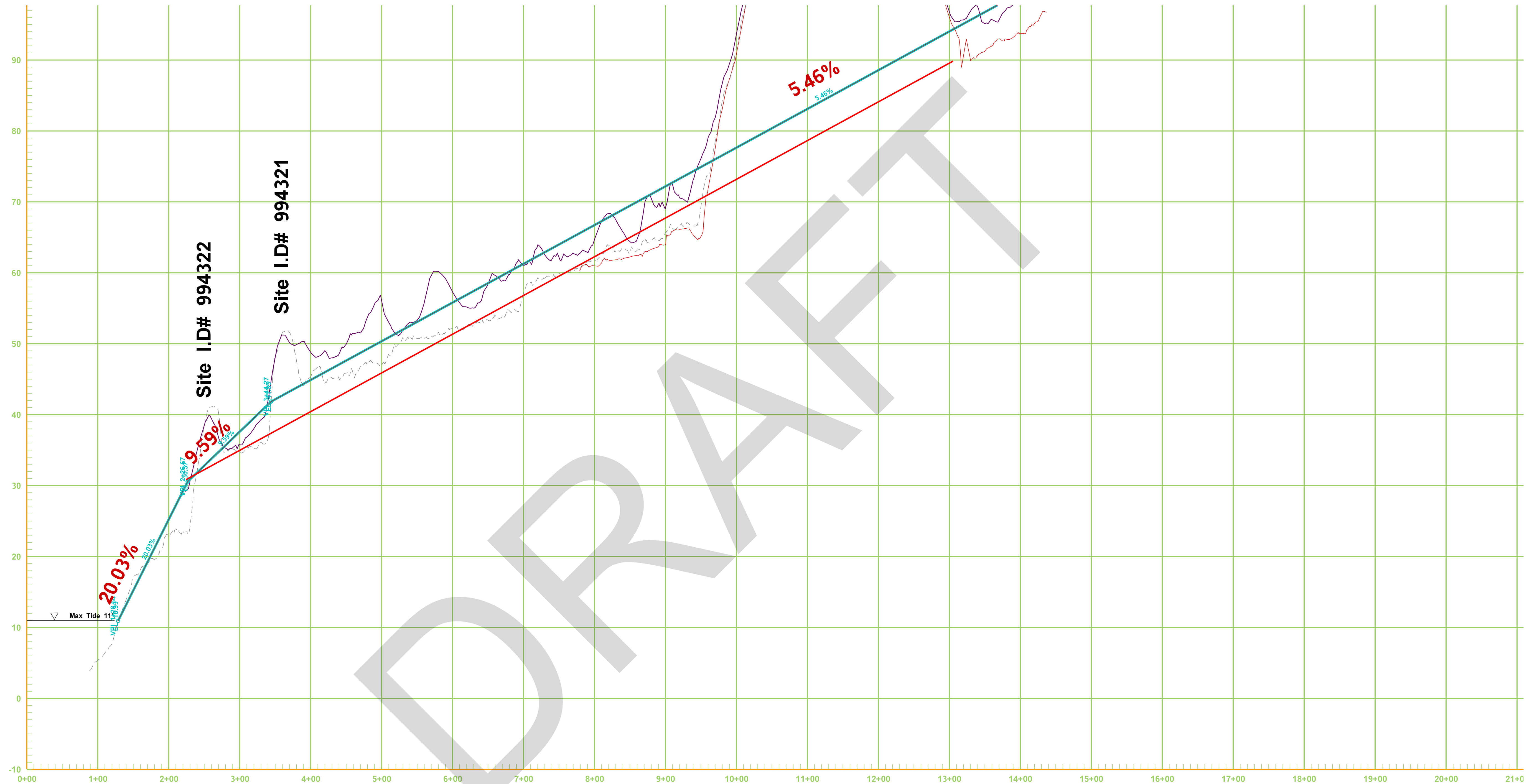






Black dots are projections from 10 separate models

Appendix F – Stream Long Profile from LiDAR Data



LEGEND

- Profile from 2002 LiDAR
- Profile from 2012 LiDAR
- Profile from Project Survey
- Estimated Prvailing Profile

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DESIGNED BY	Y. BEREDED-SAMUEL		
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CHECKED BY			
PROJ. ENGR.			
REGIONAL ADM.	REVISION	DATE	BY

REGION NO.	STATE	FED.AID PROJ.NO.
10	WASH	
JOB NUMBER		
CONTRACT NO.		LOCATION NO.

P.E. STAMP BOX DATE

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Washington State Department of Transportation

US 101 DISCOVERT CREEK
LONG PROFILE

DOWNSTREAM

Plot 1

PLAN REF. NO.

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OF

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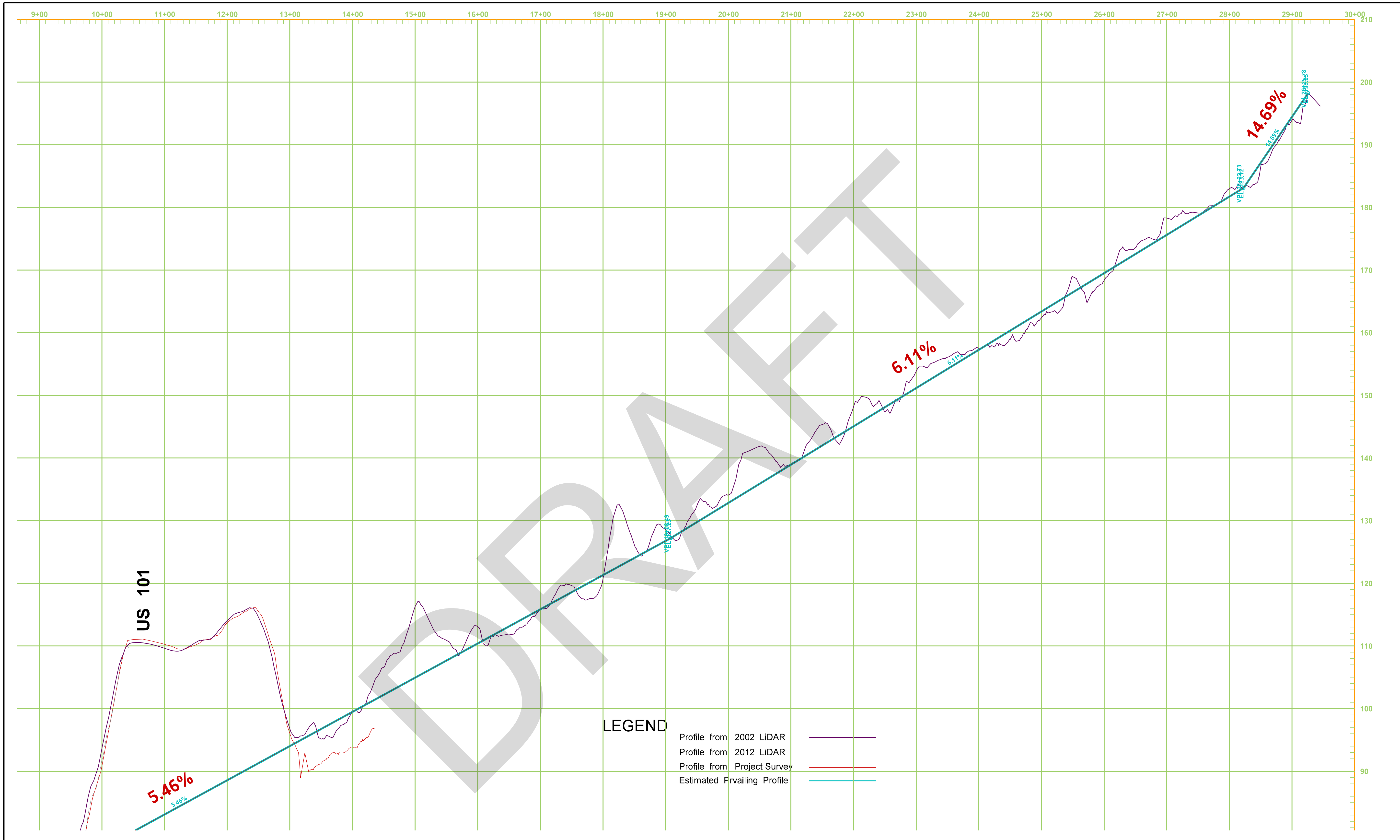

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CHECKED BY			
PROJ. ENGR.			
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REGION NO.	STATE	FED.AID PROJ.NO.
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Washington State
Department of Transportation

US 101 DISCOVERT CREEK
LONG PROFILE

UPSTREAM

Plot 2
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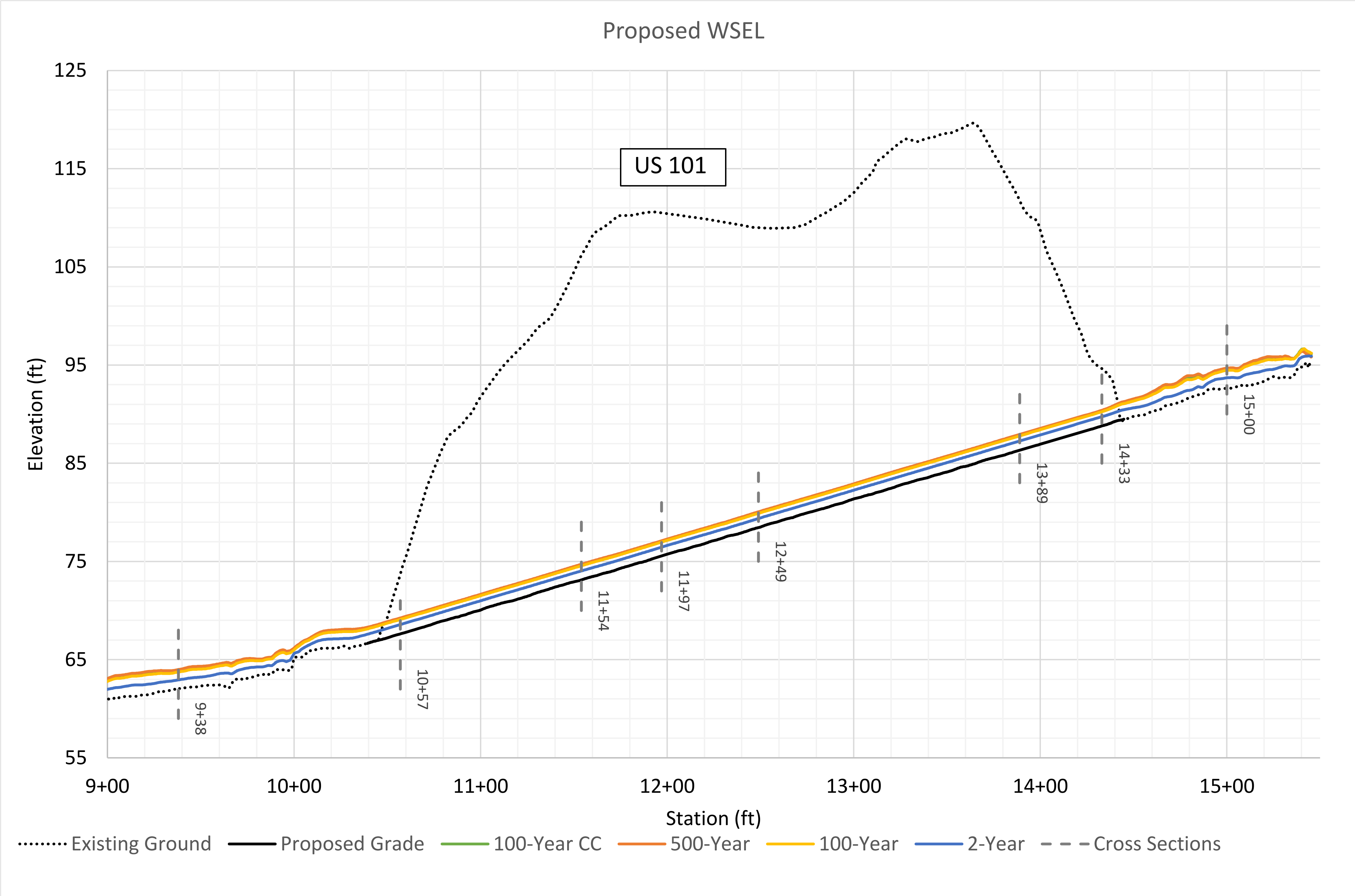
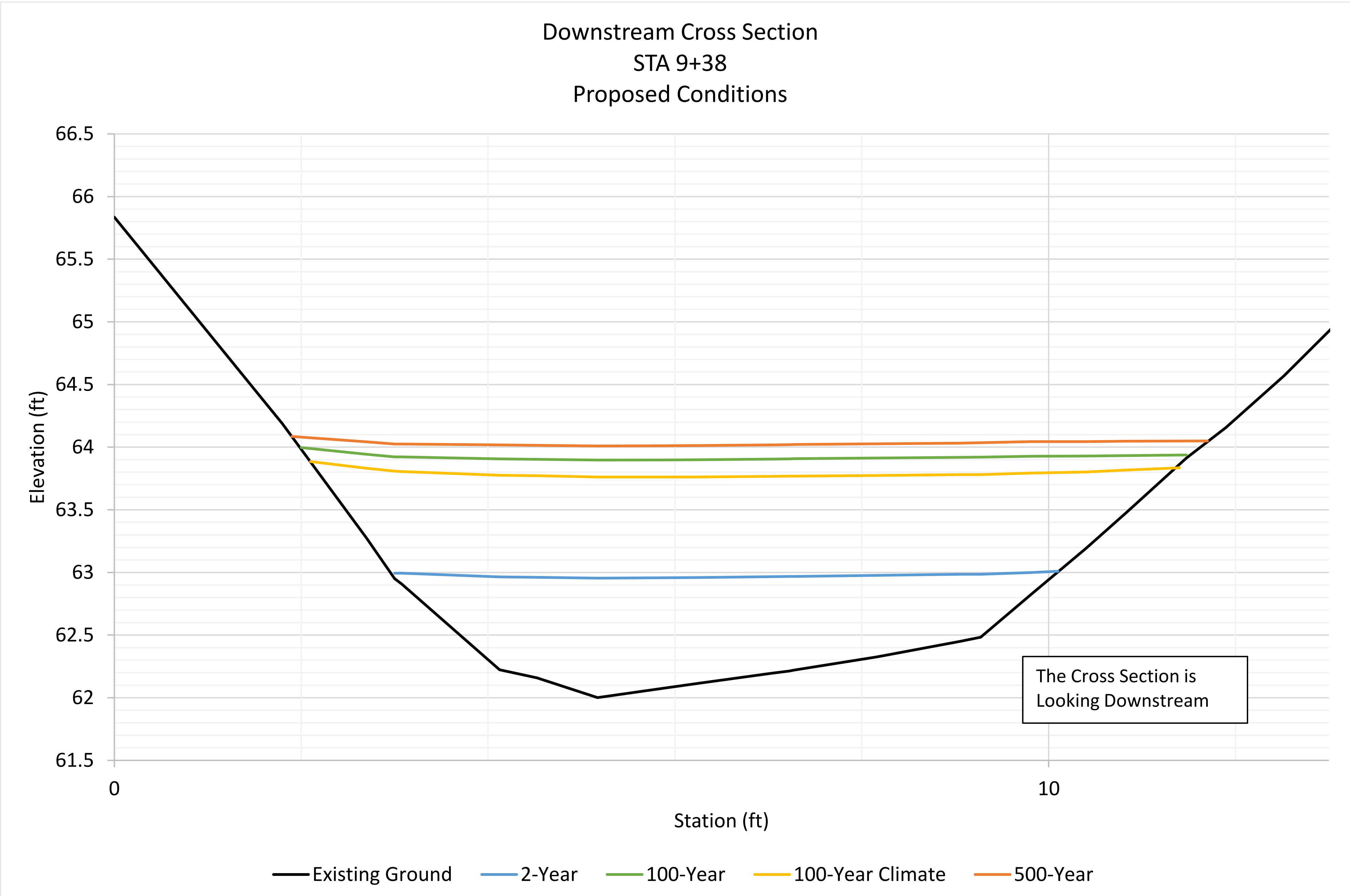
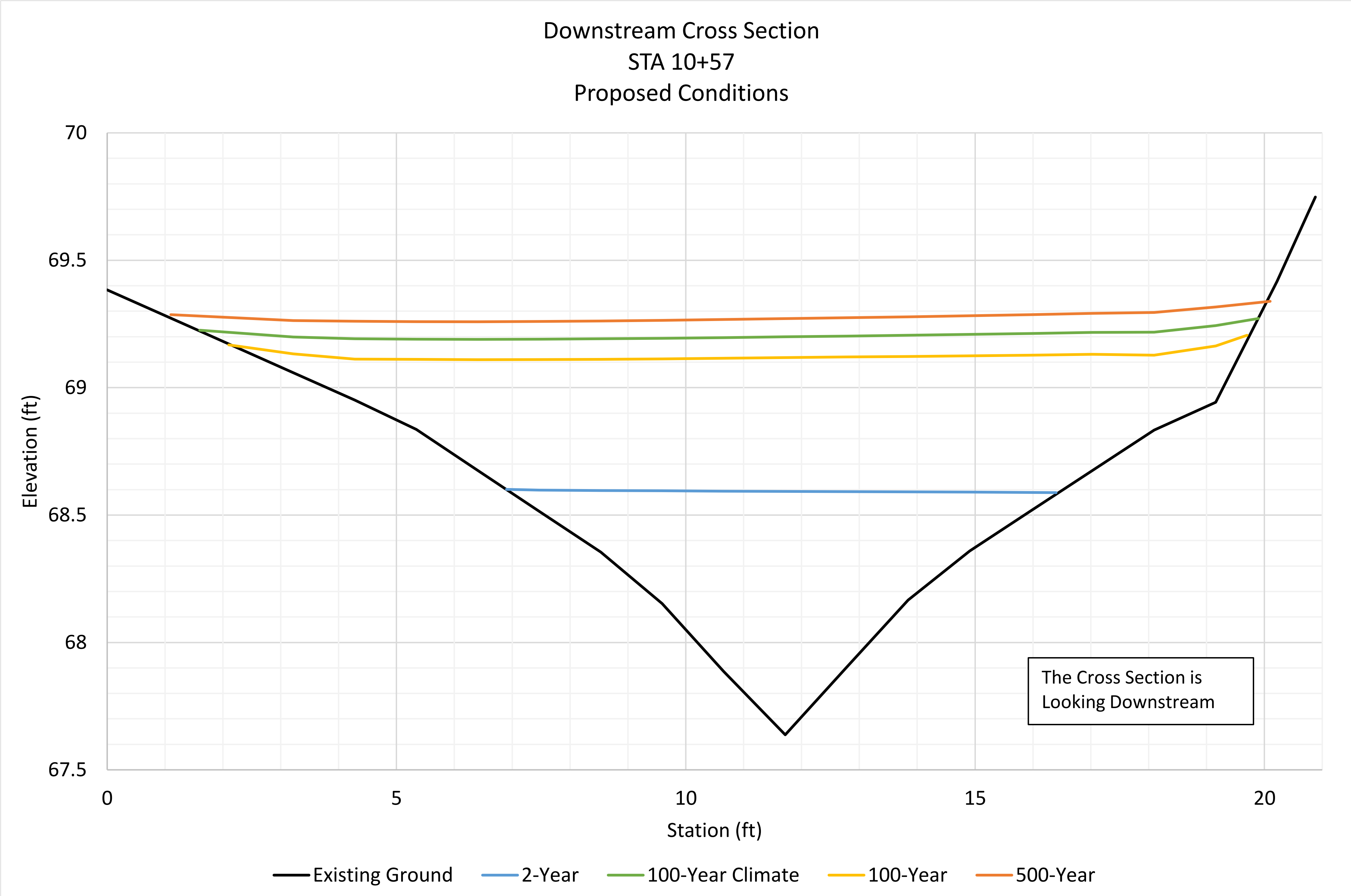
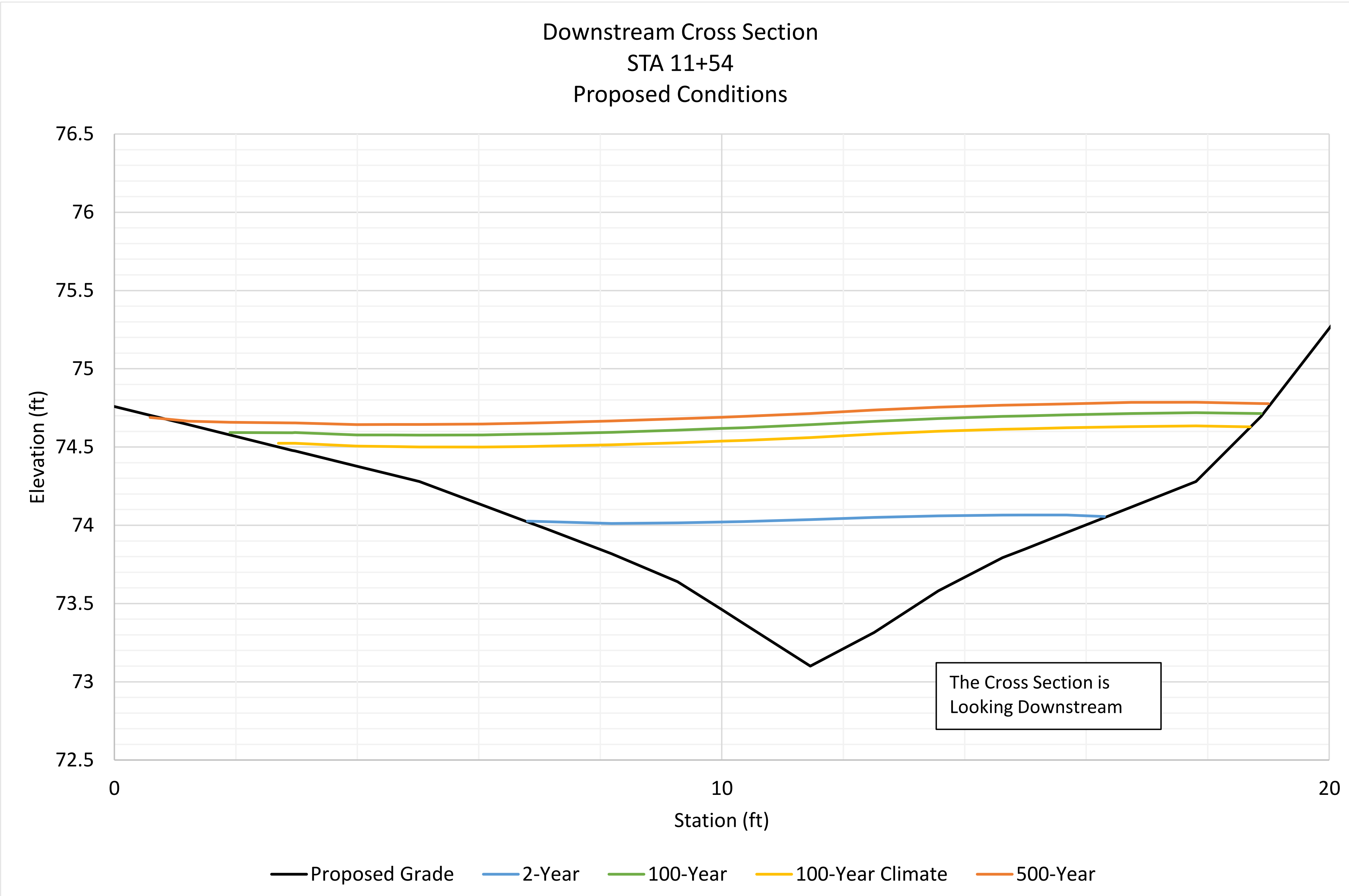
Appendix B: SRH-2D Model Results

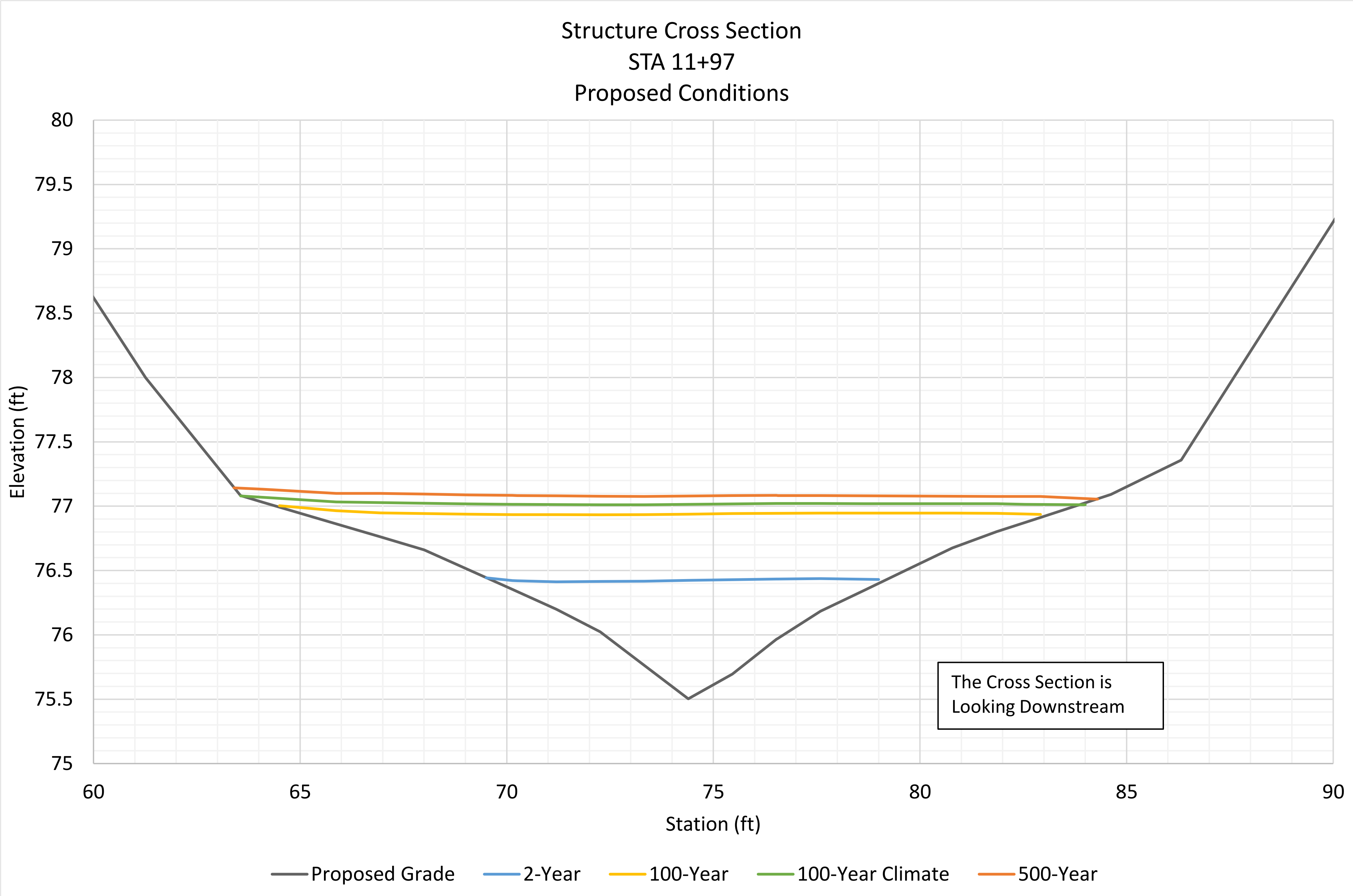


Proposed WSEL
US 101
125
115
105
95
85
75
65
55
Elevation (ft)
9+00
10+00
11+00
12+00
13+00
14+00
15+00
Station (ft)
9+38
10+57
11+54
11+97
12+49
13+89
14+33
15+00
Existing Ground
Proposed Grade
100-Year CC
500-Year
100-Year
2-Year
Cross Sections

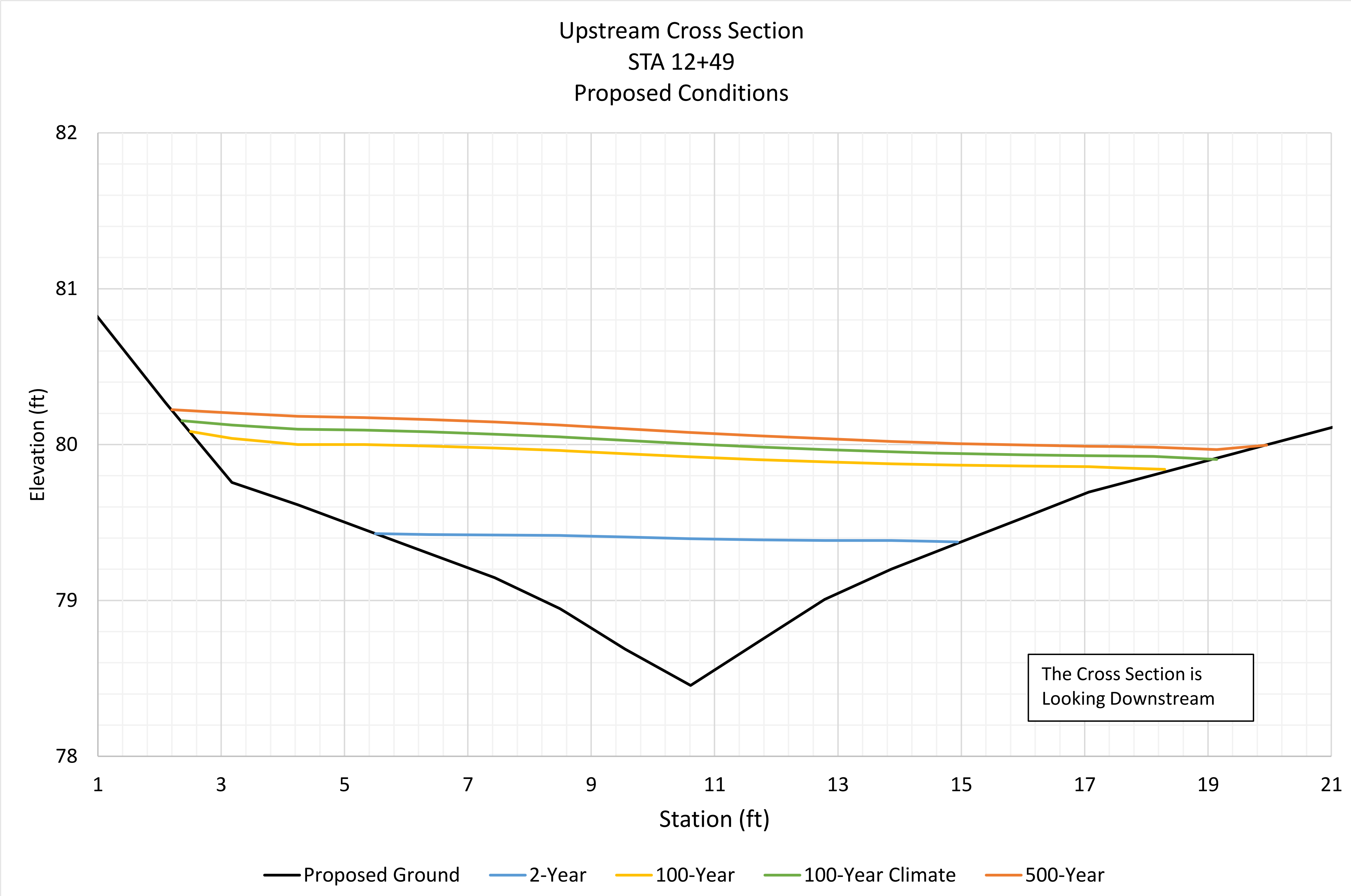

Downstream Cross Section
STA 9+38
Proposed Conditions
66.5
66
65.5
65
64.5
64
63.5
63
62.5
62
61.5
Elevation (ft)
0
10
Station (ft)
The Cross Section is Looking Downstream
Existing Ground
2-Year
100-Year
100-Year Climate
500-Year

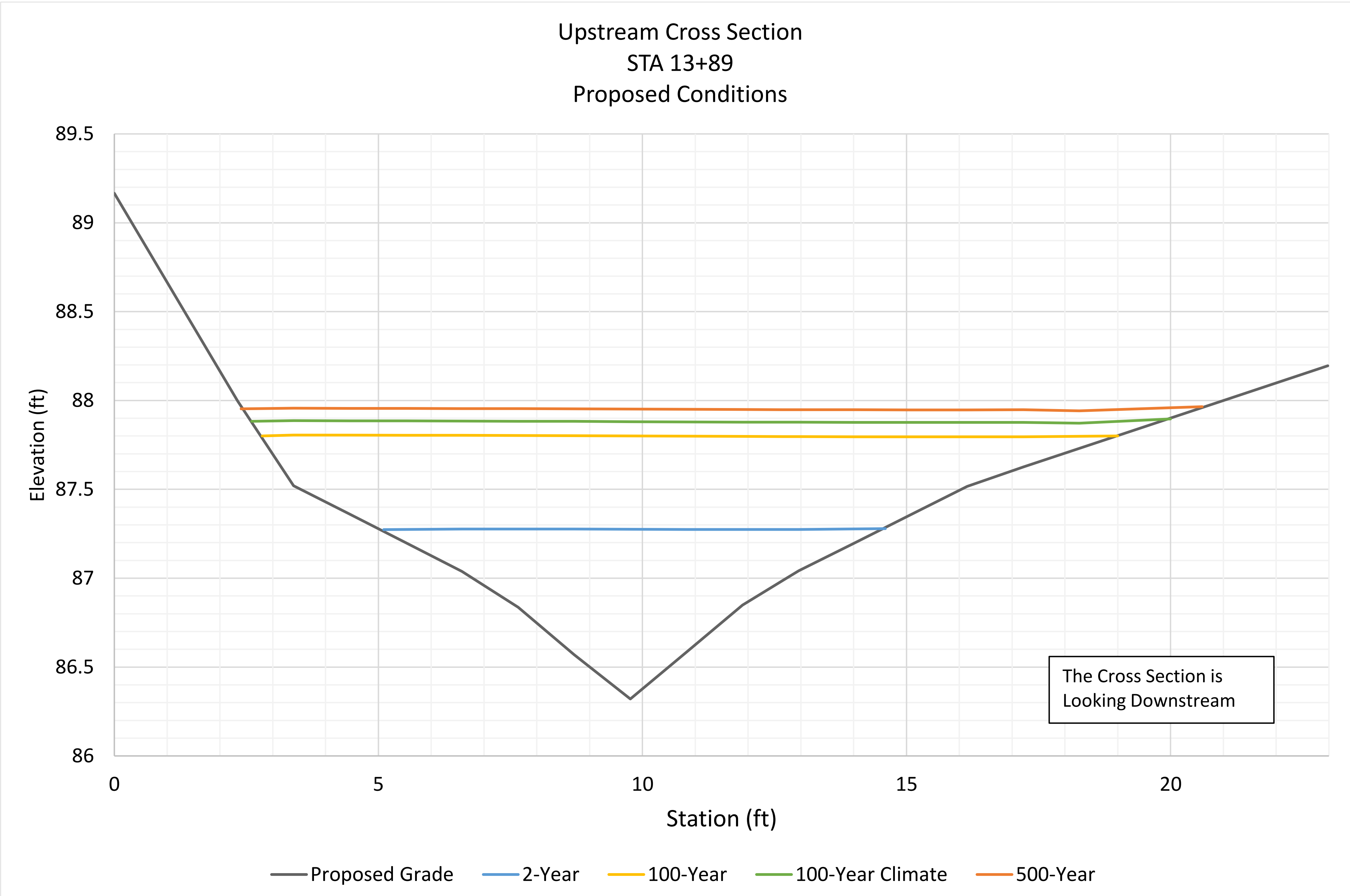

Downstream Cross Section
STA 10+57
Proposed Conditions
Elevation (ft)
70
69.5
69
68.5
68
67.5
0
5
10
15
20
Station (ft)
The Cross Section is Looking Downstream
Existing Ground
2-Year
100-Year Climate
100-Year
500-Year

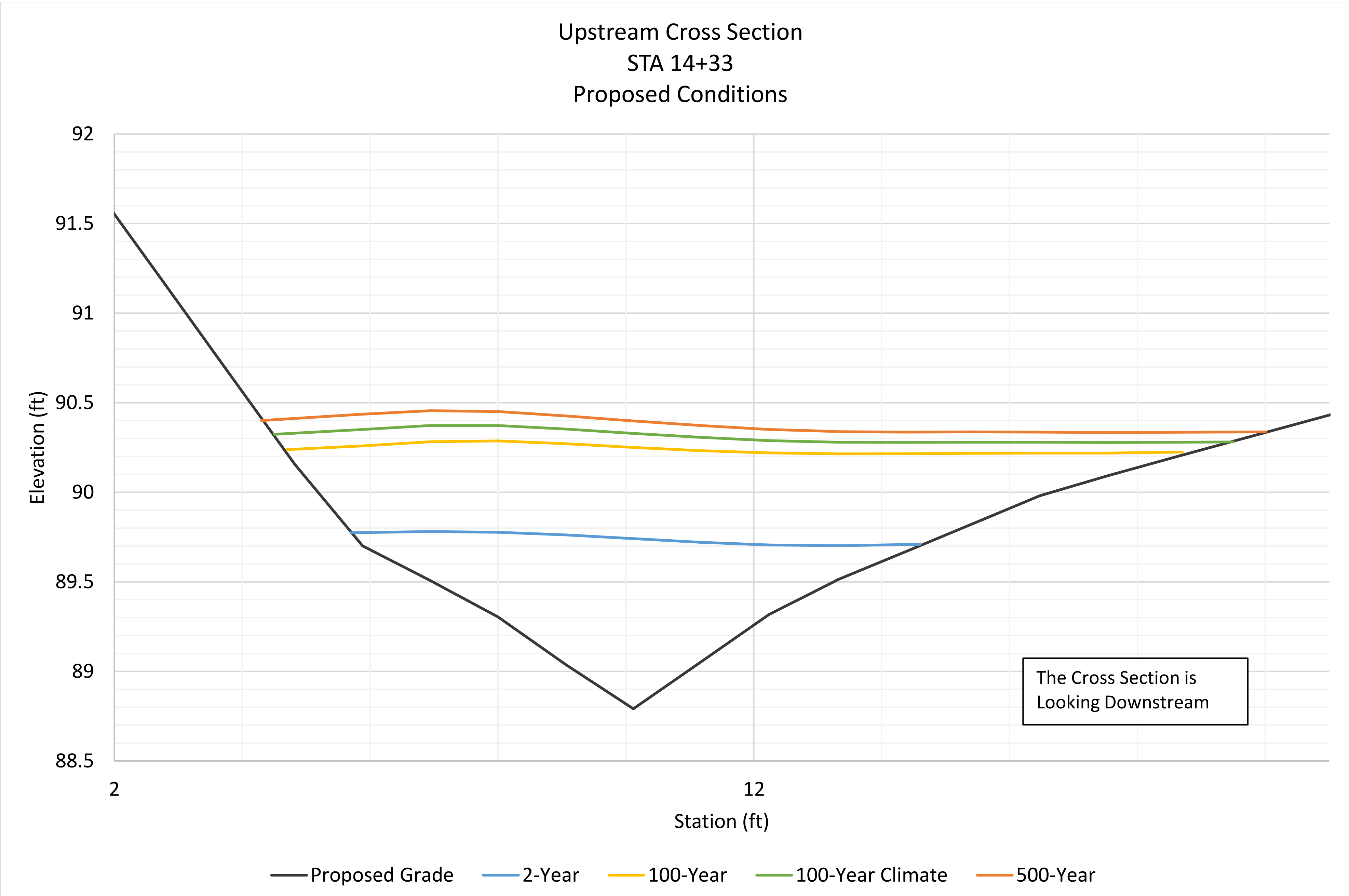

Downstream Cross Section
STA 11+54
Proposed Conditions
76.5
76
75.5
75
74.5
74
73.5
73
72.5
0
10
20
Elevation (ft)
Station (ft)
The Cross Section is
Looking Downstream
Proposed Grade
2-Year
100-Year
100-Year Climate
500-Year

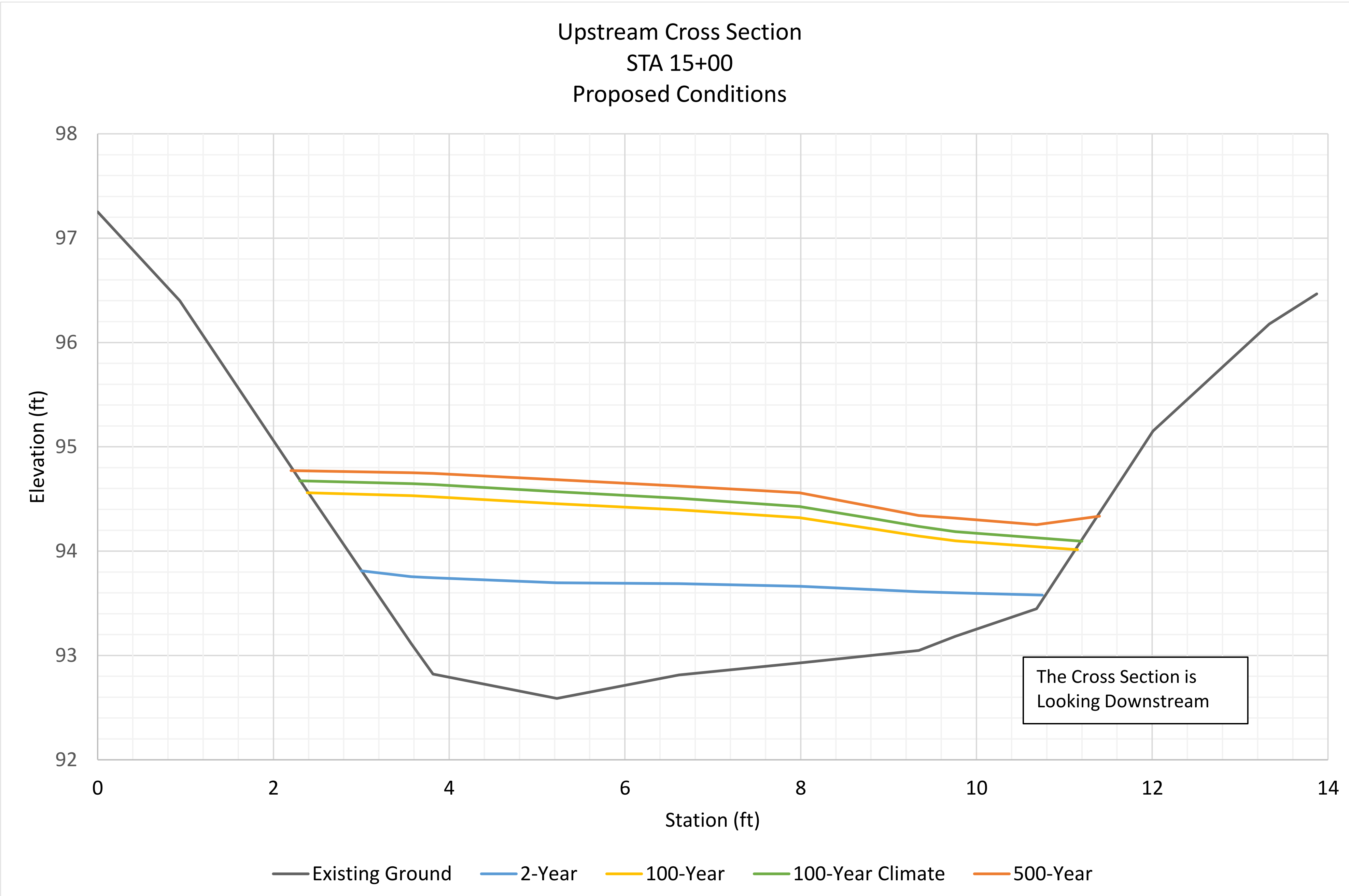


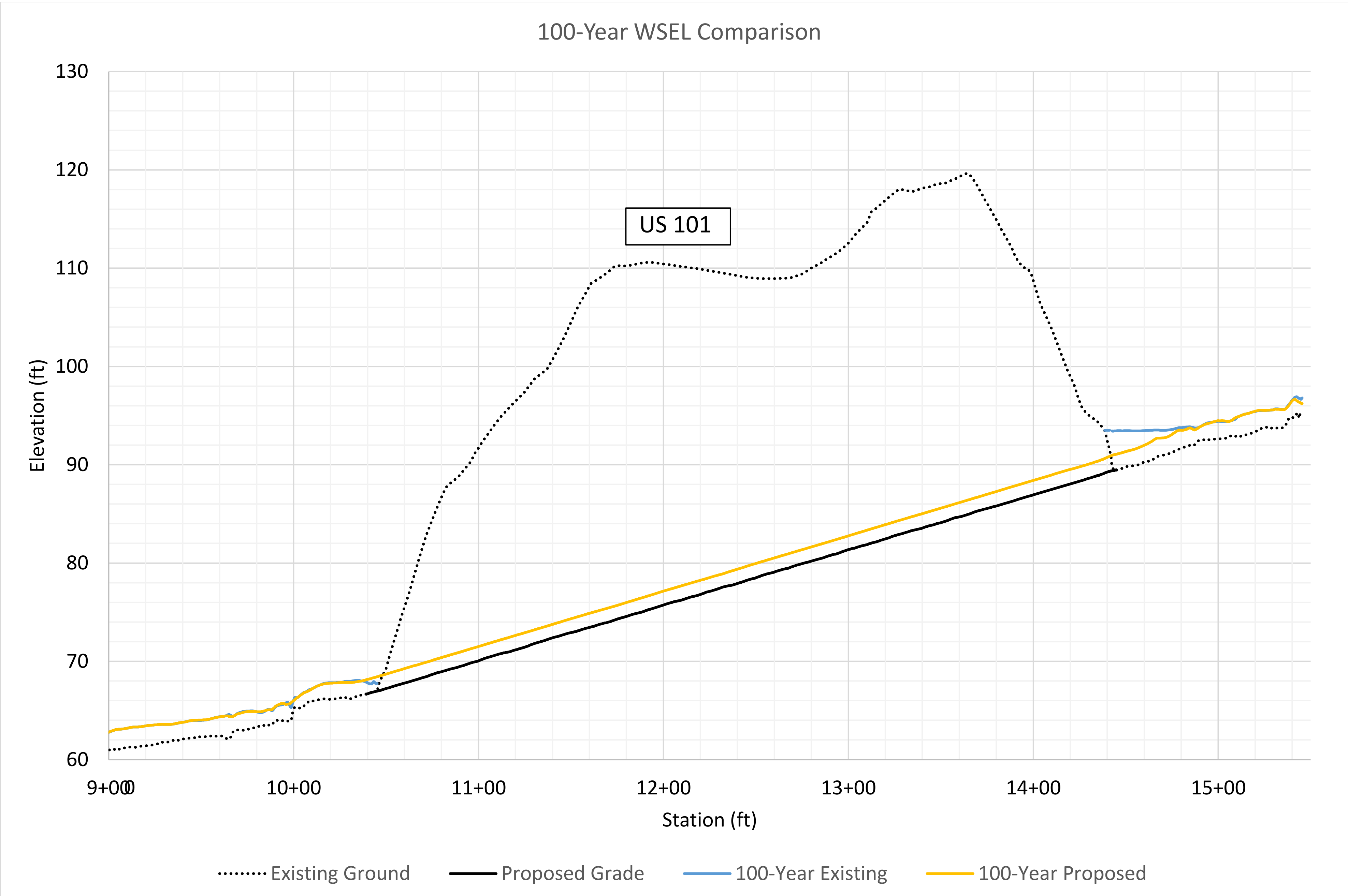
Structure Cross Section
STA 11+97
Proposed Conditions
Elevation (ft)
Station (ft)
80
79.5
79
78.5
78
77.5
77
76.5
76
75.5
75
60
65
70
75
80
85
90
The Cross Section is Looking Downstream
Proposed Grade
2-Year
100-Year
100-Year Climate
500-Year


Upstream Cross Section
STA 12+49
Proposed Conditions
Elevation (ft)
82
81
80
79
78
1
3
5
7
9
11
13
15
17
19
21
Station (ft)
The Cross Section is
Looking Downstream
Proposed Ground
2-Year
100-Year
100-Year Climate
500-Year

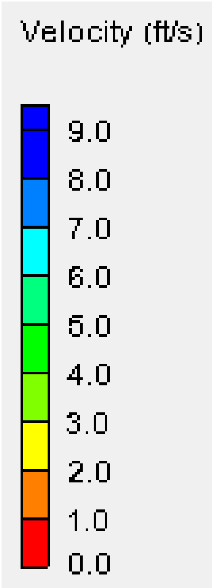

Upstream Cross Section
STA 13+89
Proposed Conditions
Elevation (ft)
89.5
89
88.5
88
87.5
87
86.5
86
0
5
10
15
20
Station (ft)
The Cross Section is Looking Downstream
Proposed Grade
2-Year
100-Year
100-Year Climate
500-Year

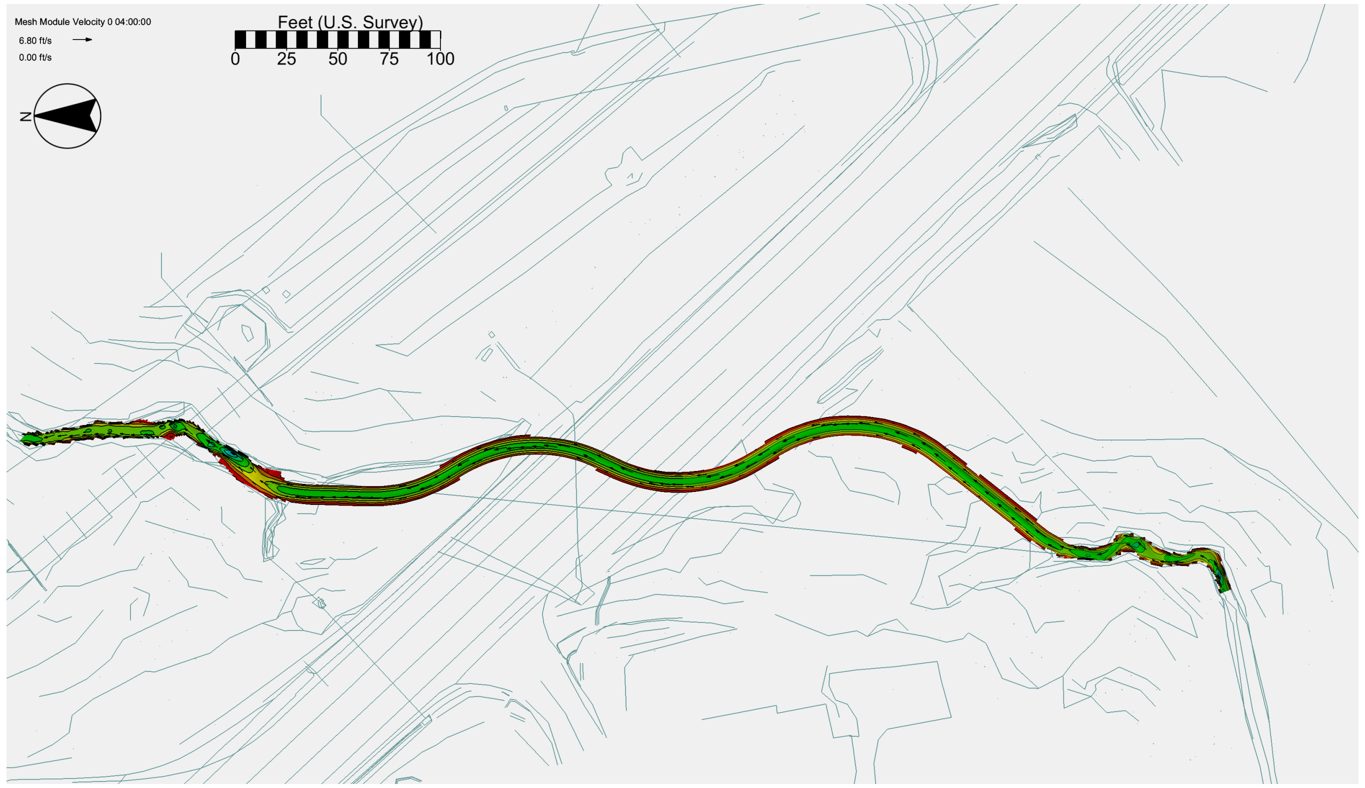

Upstream Cross Section
STA 14+33
Proposed Conditions
92
91.5
91
90.5
90
89.5
89
88.5
Elevation (ft)
2
12
Station (ft)
The Cross Section is Looking Downstream
Proposed Grade
2-Year
100-Year
100-Year Climate
500-Year


Upstream Cross Section
STA 15+00
Proposed Conditions
Elevation (ft)
98
97
96
95
94
93
92
0
2
4
6
8
10
12
14
Station (ft)
The Cross Section is Looking Downstream
Existing Ground
2-Year
100-Year
100-Year Climate
500-Year

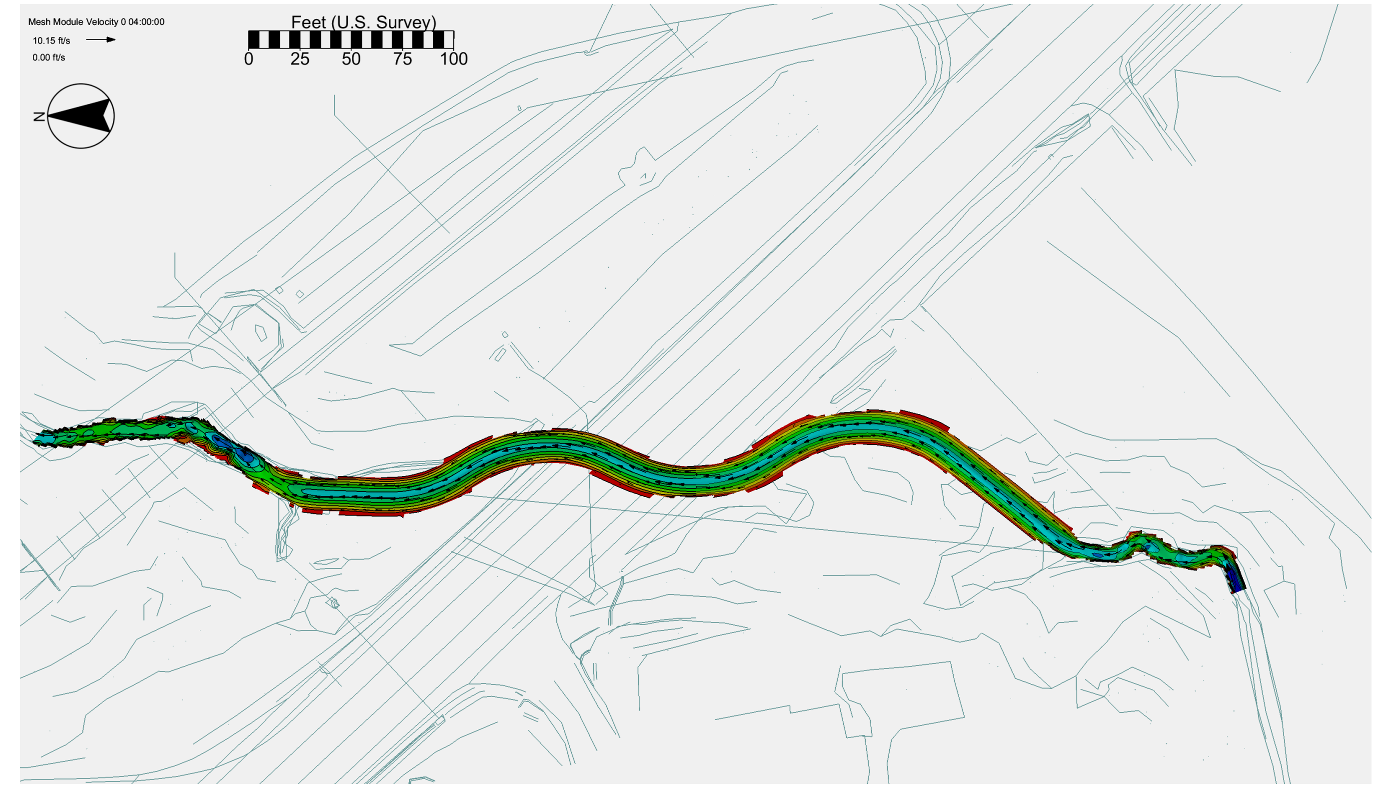

100-Year WSEL Comparison
US 101
130
120
110
100
90
80
70
60
Elevation (ft)
9+00
10+00
11+00
12+00
13+00
14+00
15+00
Station (ft)
Existing Ground
Proposed Grade
100-Year Existing
100-Year Proposed

US 101 MP 268.54 - Velocity

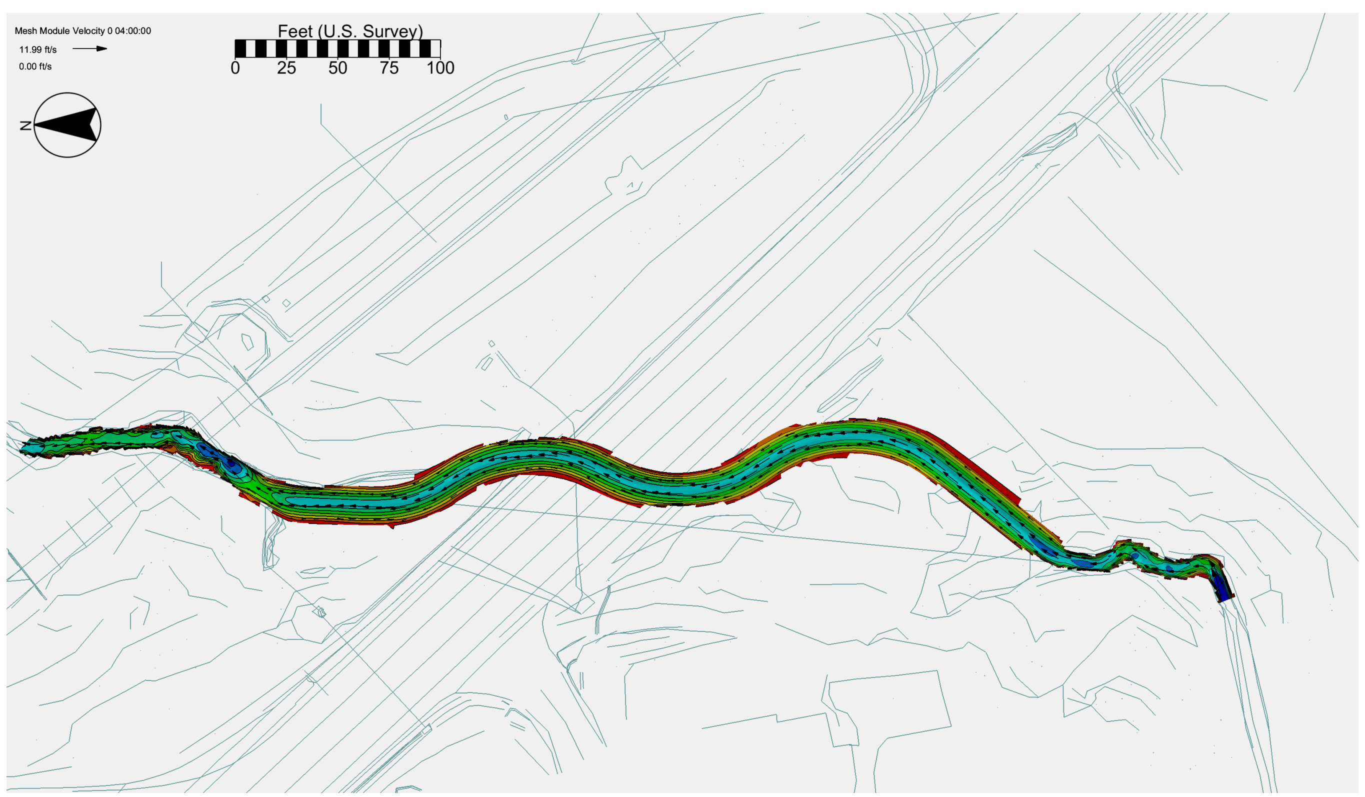




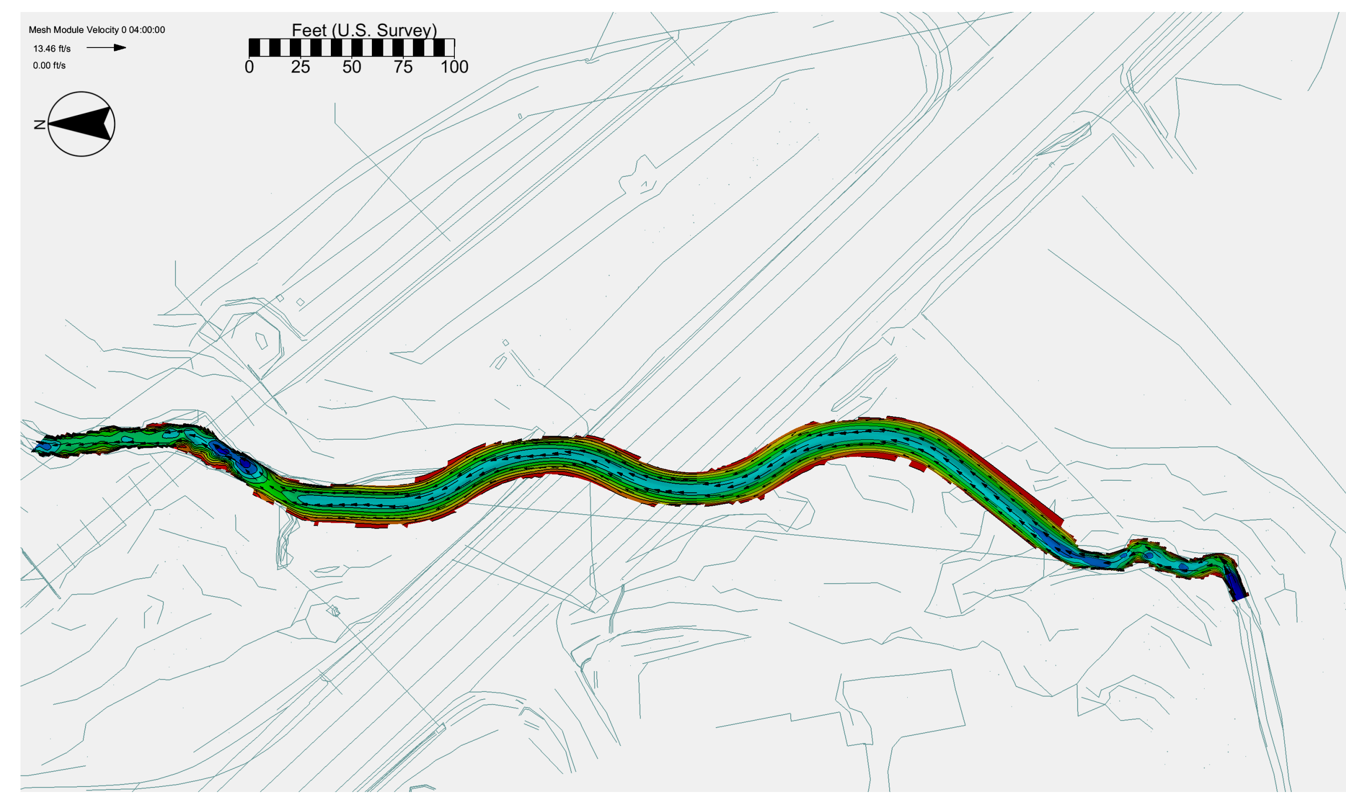
2-Year Velocity



100-Year Velocity

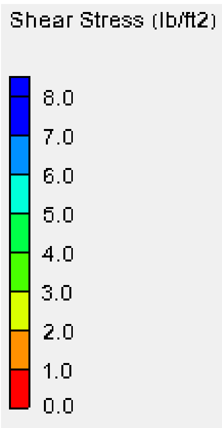


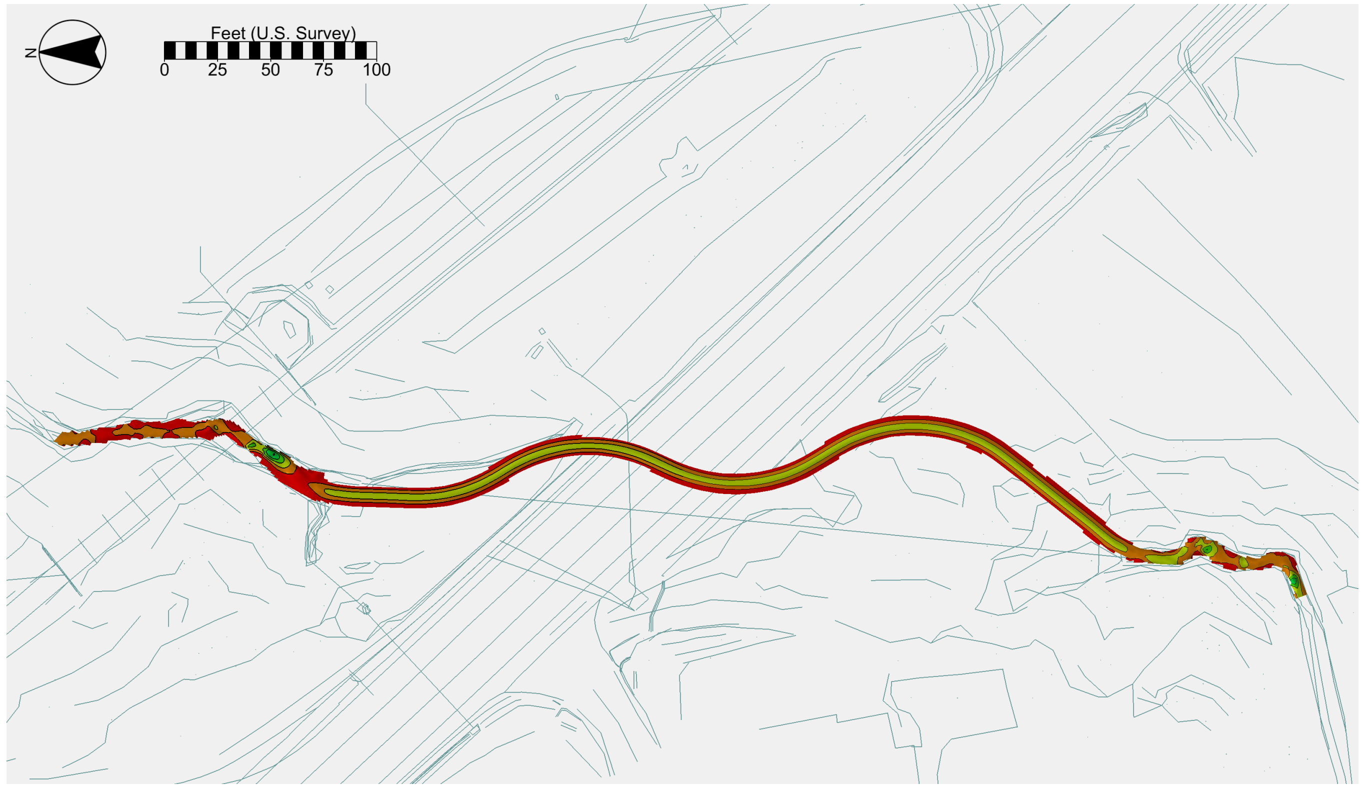
100-Year 2040 Velocity



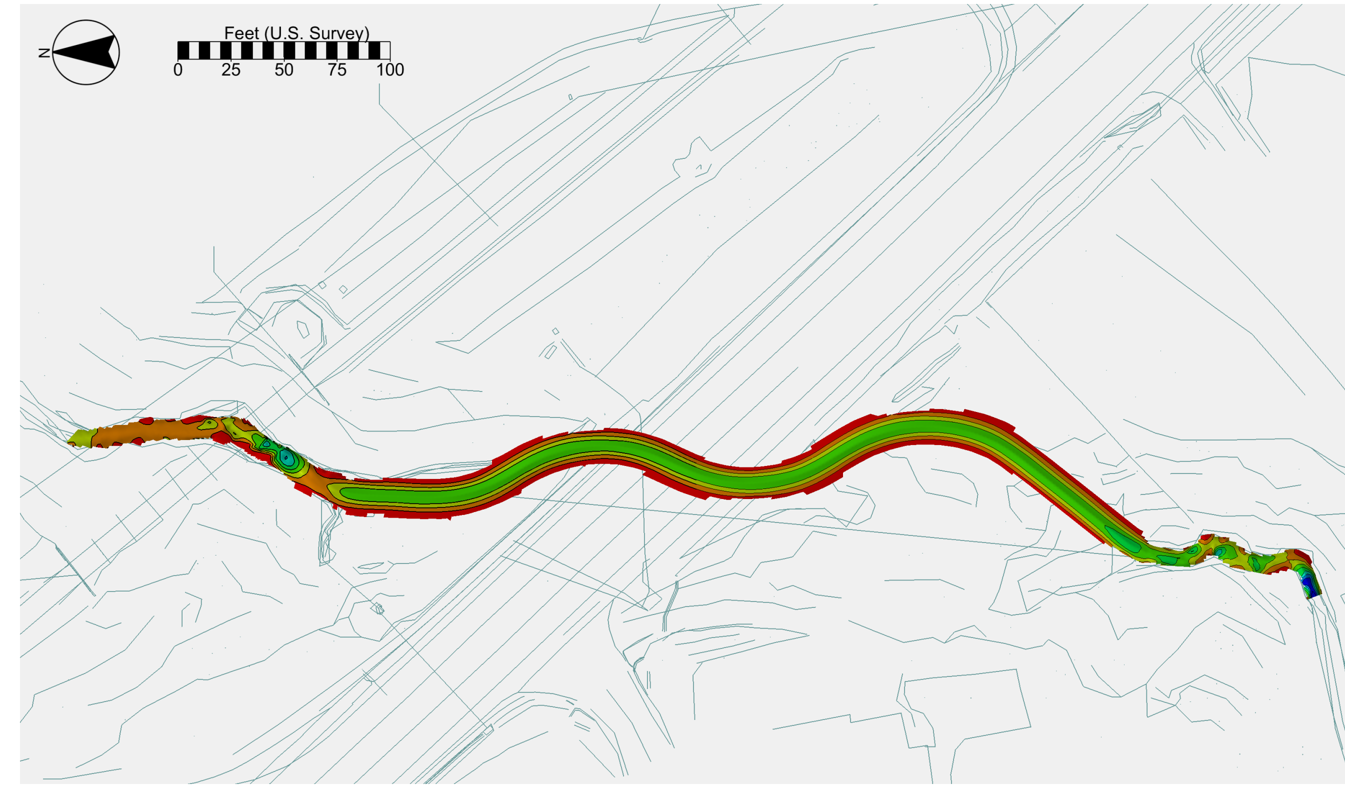
500-Year Velocity

US 101 MP 268.54 - Shear Stress

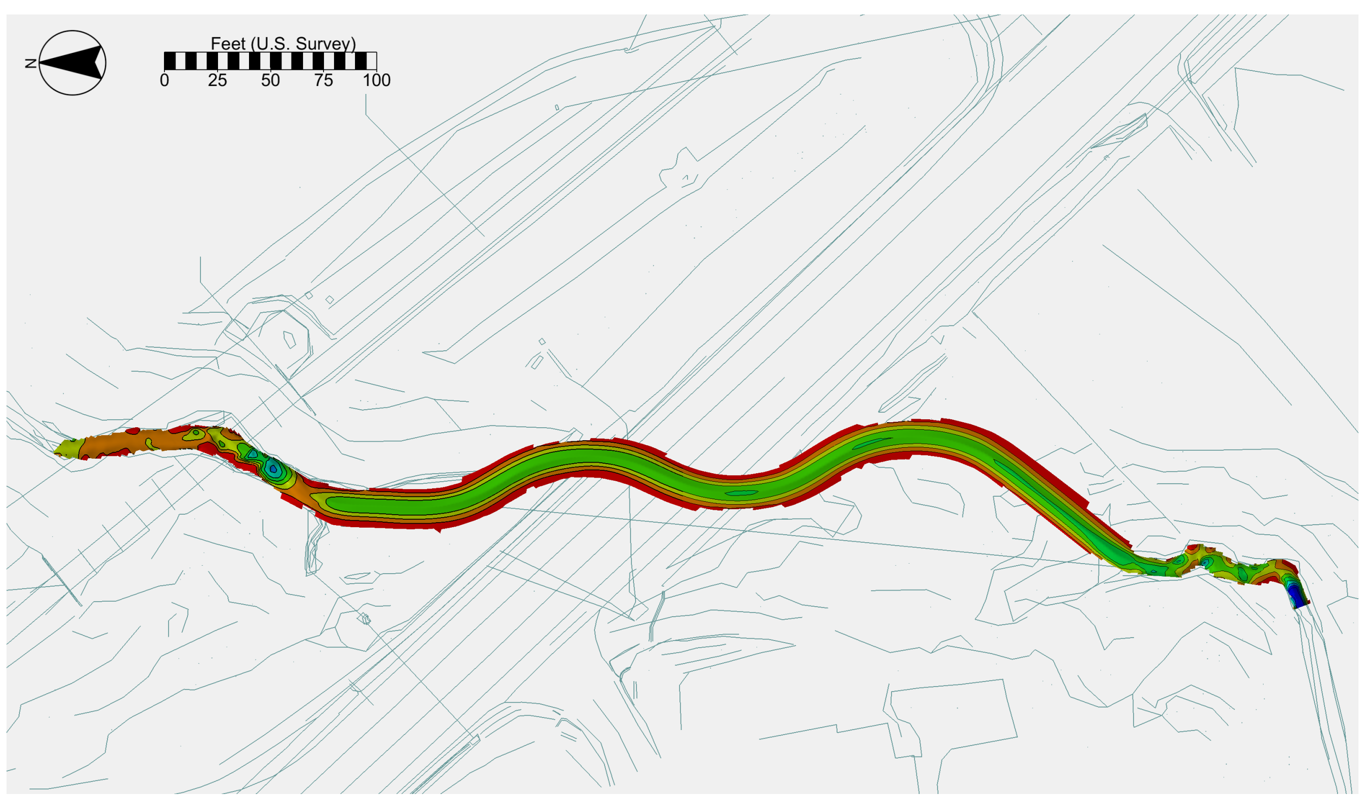




2-Year Shear Stress



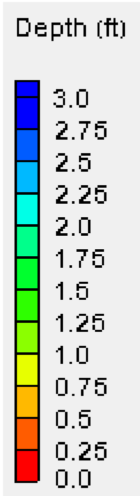
100-Year Shear Stress



100-Year 2040 Shear Stress

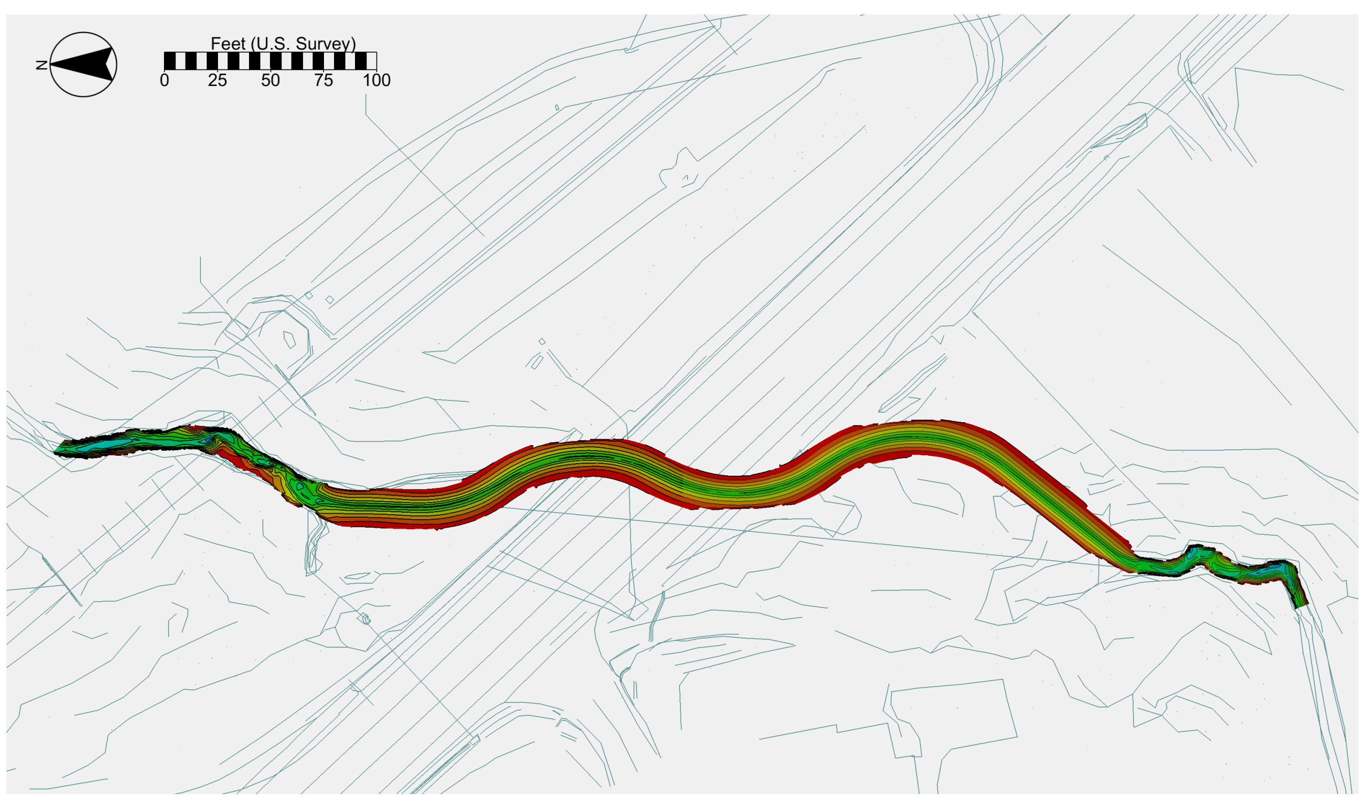
500-Year Shear Stress

US 101 MP 268.54 - Water Depth

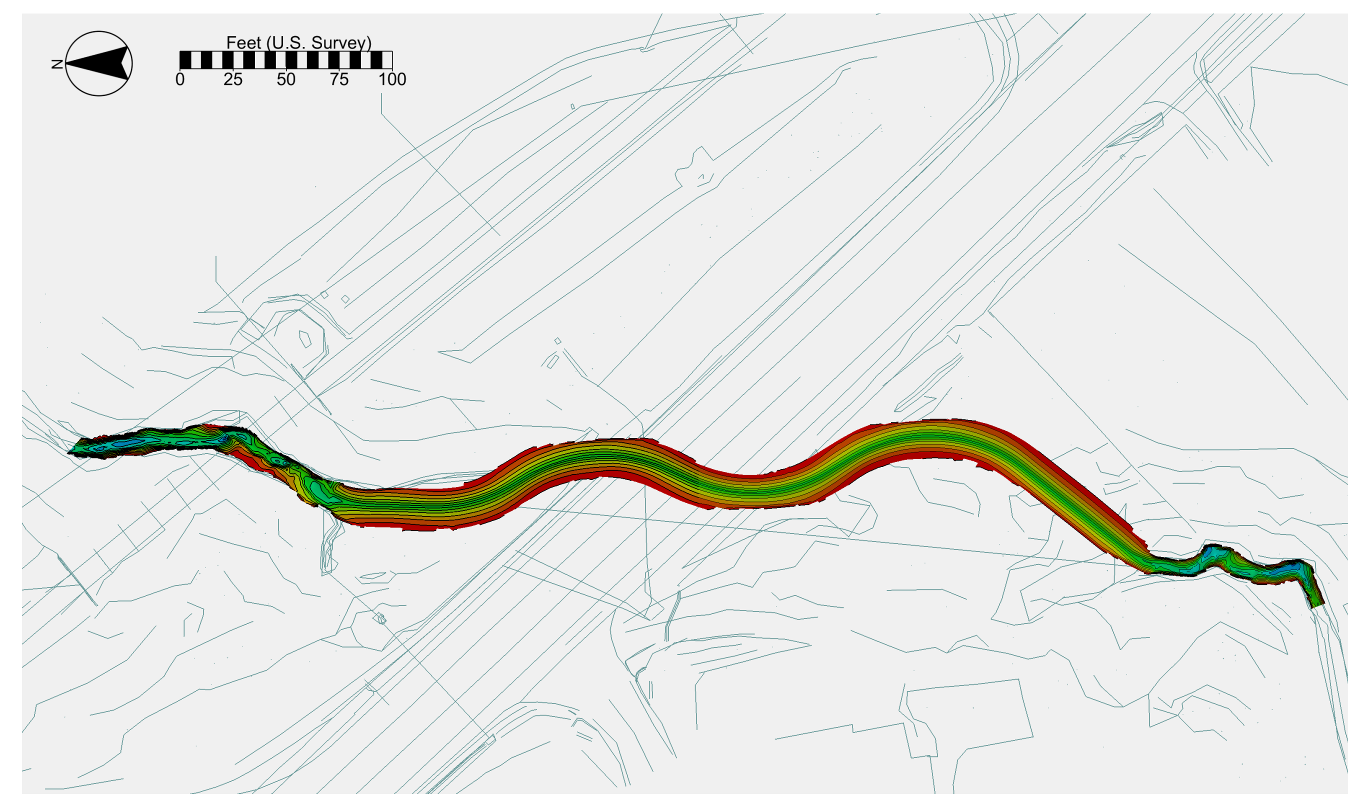


2-Year Depth

100-Year Depth

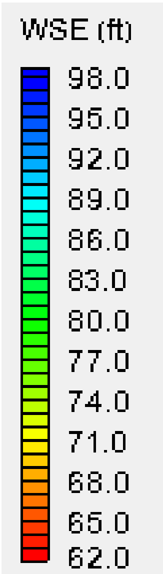


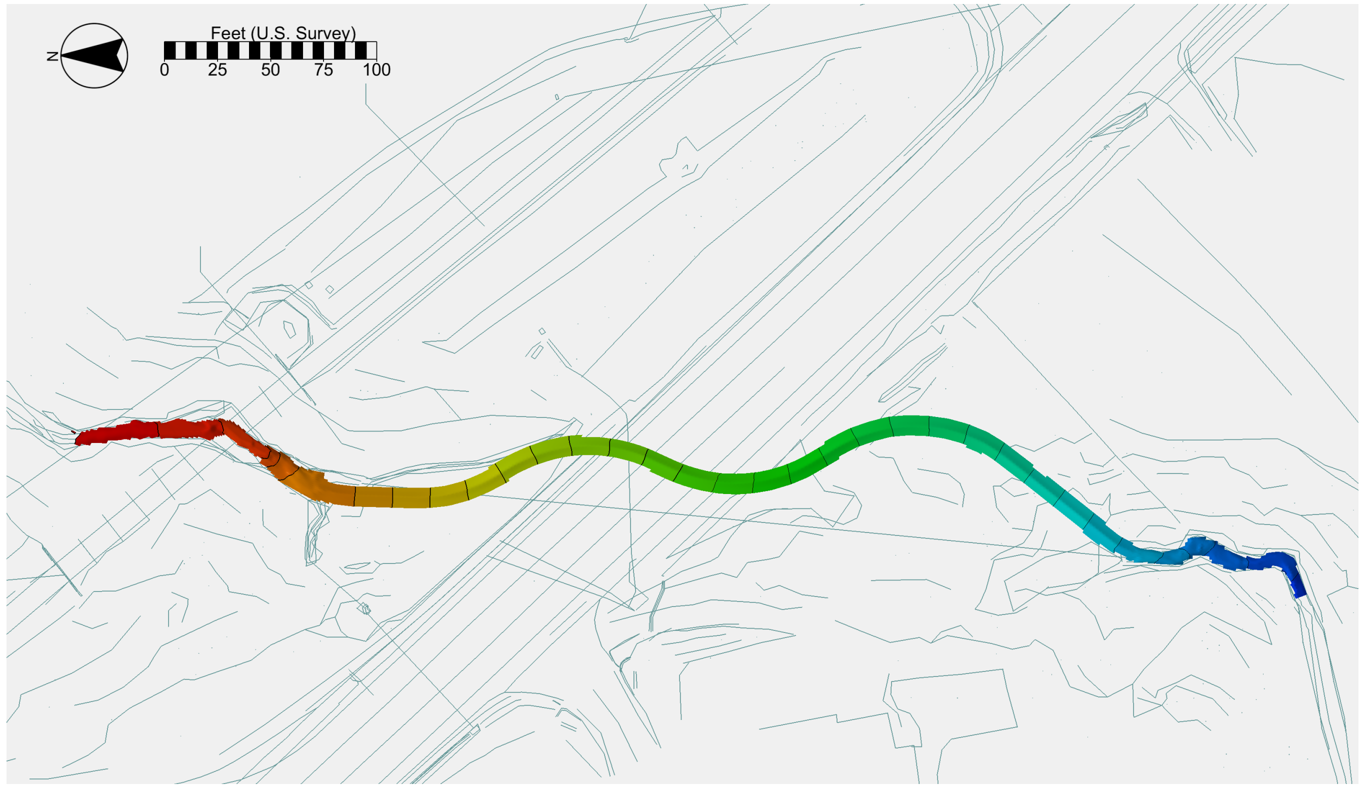
100-Year 2040 Depth



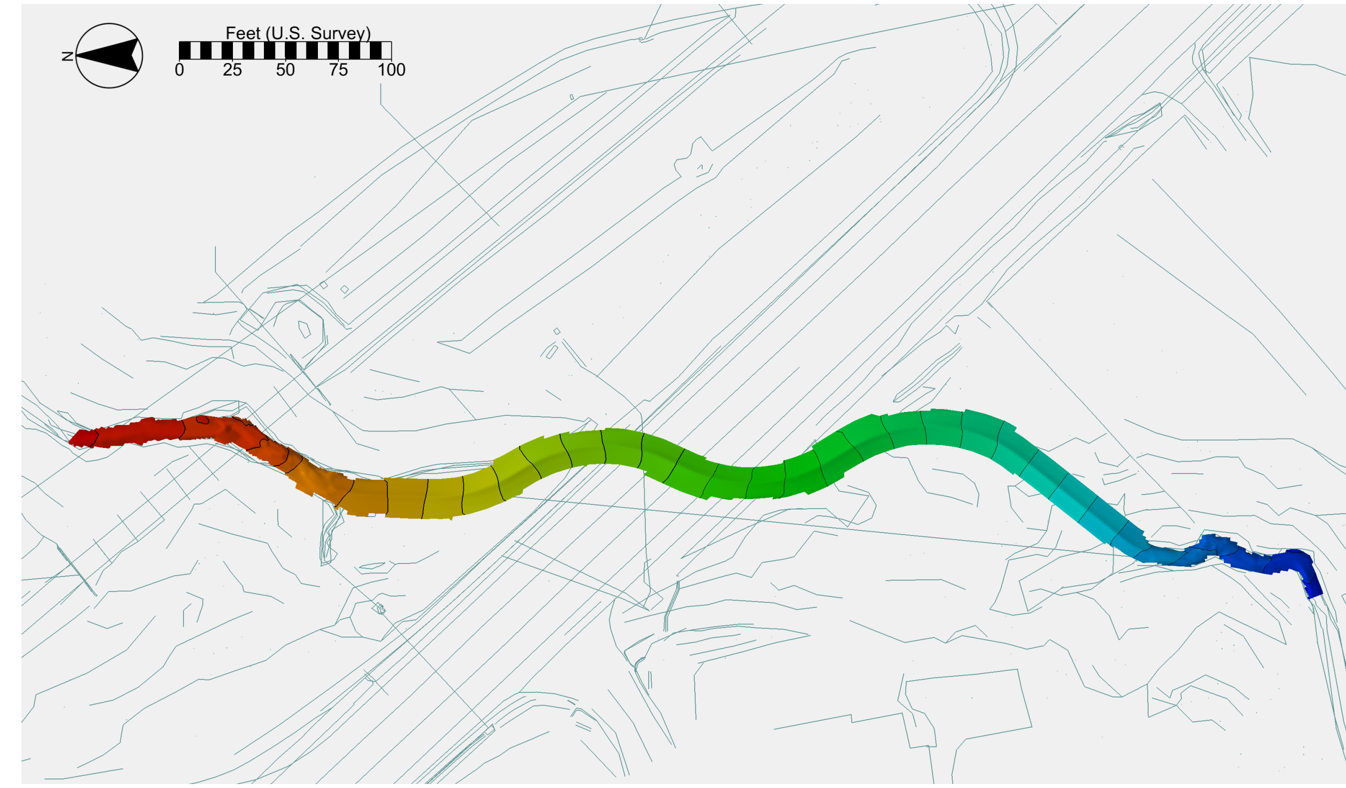
500-Year Depth

US 101 MP 268.54 - Water Surface Elevations

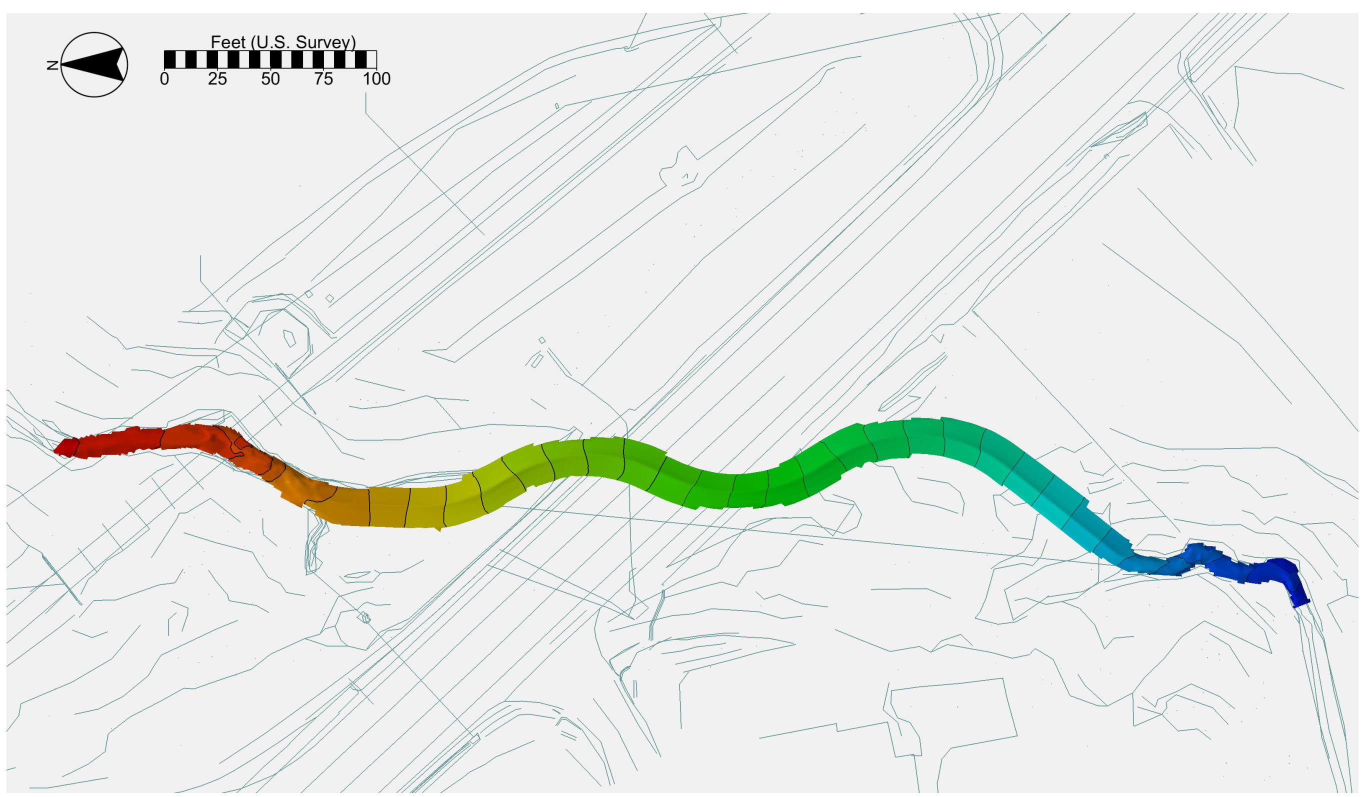




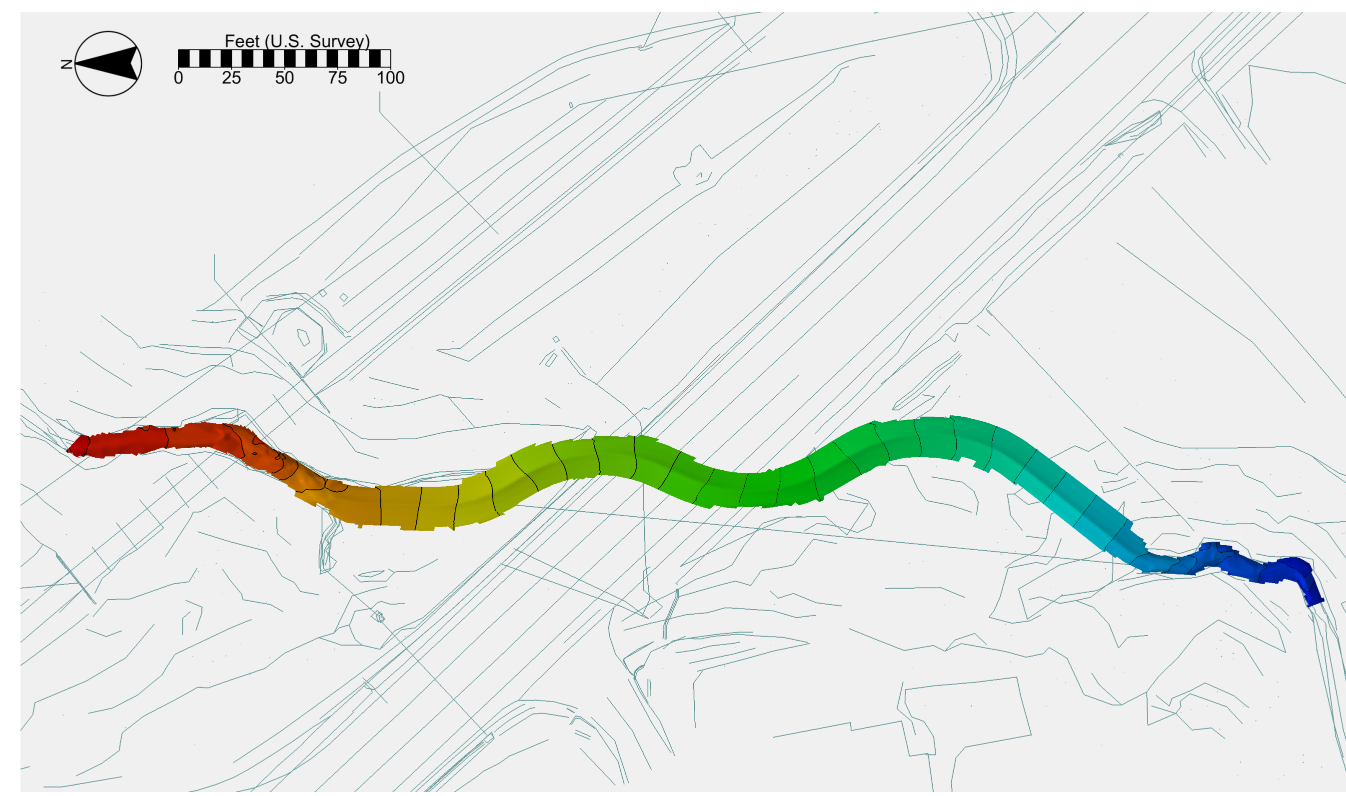
2-Year Water Surface Elevation



100-Year Water Surface Elevation



100-Year 2040 Water Surface Elevation



500-Year Water Surface Elevation

Appendix C: Large Woody Material Plan Sheet

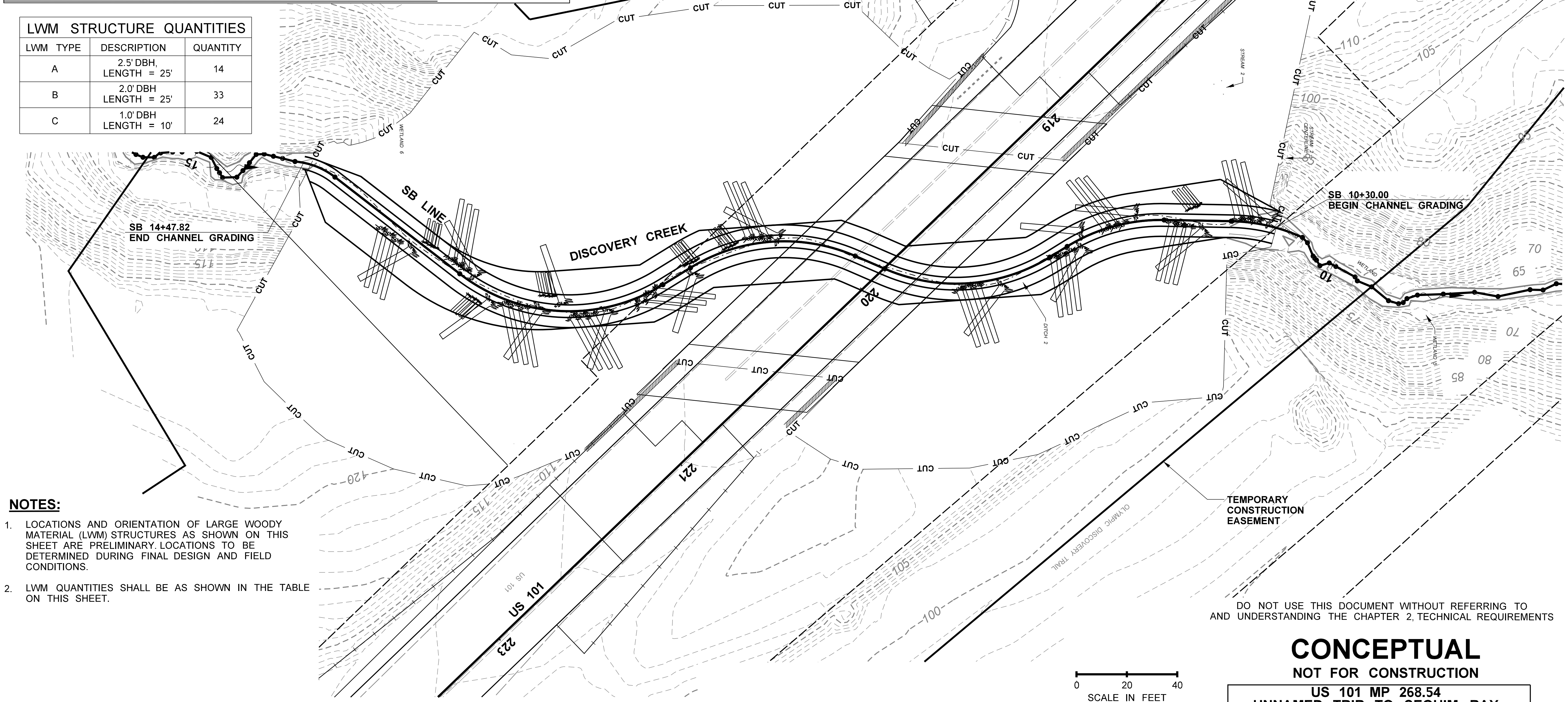
LEGEND

5	CONSTRUCTION ALIGNMENT	CUT	CONCEPTUAL CUT LIMITS
	LIMITED ACCESS RIGHT OF WAY	FILL	CONCEPTUAL FILL LIMITS
	PROPERTY LINE		GUARDRAIL
	TEMPORARY CONSTRUCTION EASEMENT	2:1	PROPOSED GRADING SLOPE LINE
	EXISTING DITCH		PROPOSED CHANNEL GRADE BREAKLINE
	EXISTING EDGE LINE		PROPOSED LOW FLOW CHANNEL GRADING
	EXISTING EDGE OF PAVEMENT		DIRECTION OF FLOW
	EXISTING STREAM BREAKLINE		TYPE A
	EXISTING INDEX CONTOUR		TYPE B
	EXISTING INTERMEDIATE CONTOUR		TYPE C
	PROPOSED INDEX CONTOUR		
	PROPOSED INTERMEDIATE CONTOUR		

LWM STRUCTURE QUANTITIES

LWM TYPE	DESCRIPTION	QUANTITY
A	2.5' DBH, LENGTH = 25'	14
B	2.0' DBH LENGTH = 25'	33
C	1.0' DBH LENGTH = 10'	24

T.30N. R.3E. W.M.



NOTES:

1. LOCATIONS AND ORIENTATION OF LARGE WOODY MATERIAL (LWM) STRUCTURES AS SHOWN ON THIS SHEET ARE PRELIMINARY. LOCATIONS TO BE DETERMINED DURING FINAL DESIGN AND FIELD CONDITIONS.
2. LWM QUANTITIES SHALL BE AS SHOWN IN THE TABLE ON THIS SHEET.

DO NOT USE THIS DOCUMENT WITHOUT REFERRING TO AND UNDERSTANDING THE CHAPTER 2, TECHNICAL REQUIREMENTS

CONCEPTUAL
NOT FOR CONSTRUCTION

US 101 MP 268.54
UNNAMED TRIB TO SEQUIM BAY

FILE NAME	US101MP268.54_B_DE_LWM_001
TIME	2:52:16 PM
DATE	1/26/2021
PLOTTED BY	CosbyCla
DESIGNED BY	C. DUBOW
ENTERED BY	J. TYLER
CHECKED BY	T. NABOURS
PROJ. ENGR.	B. ELLIOTT
REGIONAL ADM.	J. WYNANDS

REVISION | DATE | BY

REGION NO. 10 | STATE WASH | FED.AID PROJ.NO.

JOB NUMBER

CONTRACT NO. | LOCATION NO. XL4679

P.E. STAMP BOX DATE

P.E. STAMP BOX DATE

Washington State Department of Transportation

Parametrix

US 101 JEFFERSON/ CLALLAM COUNTY FISH BARRIERS REMOVE FISH BARRIERS

LWM LAYOUT

PLAN REF NO DE1-B

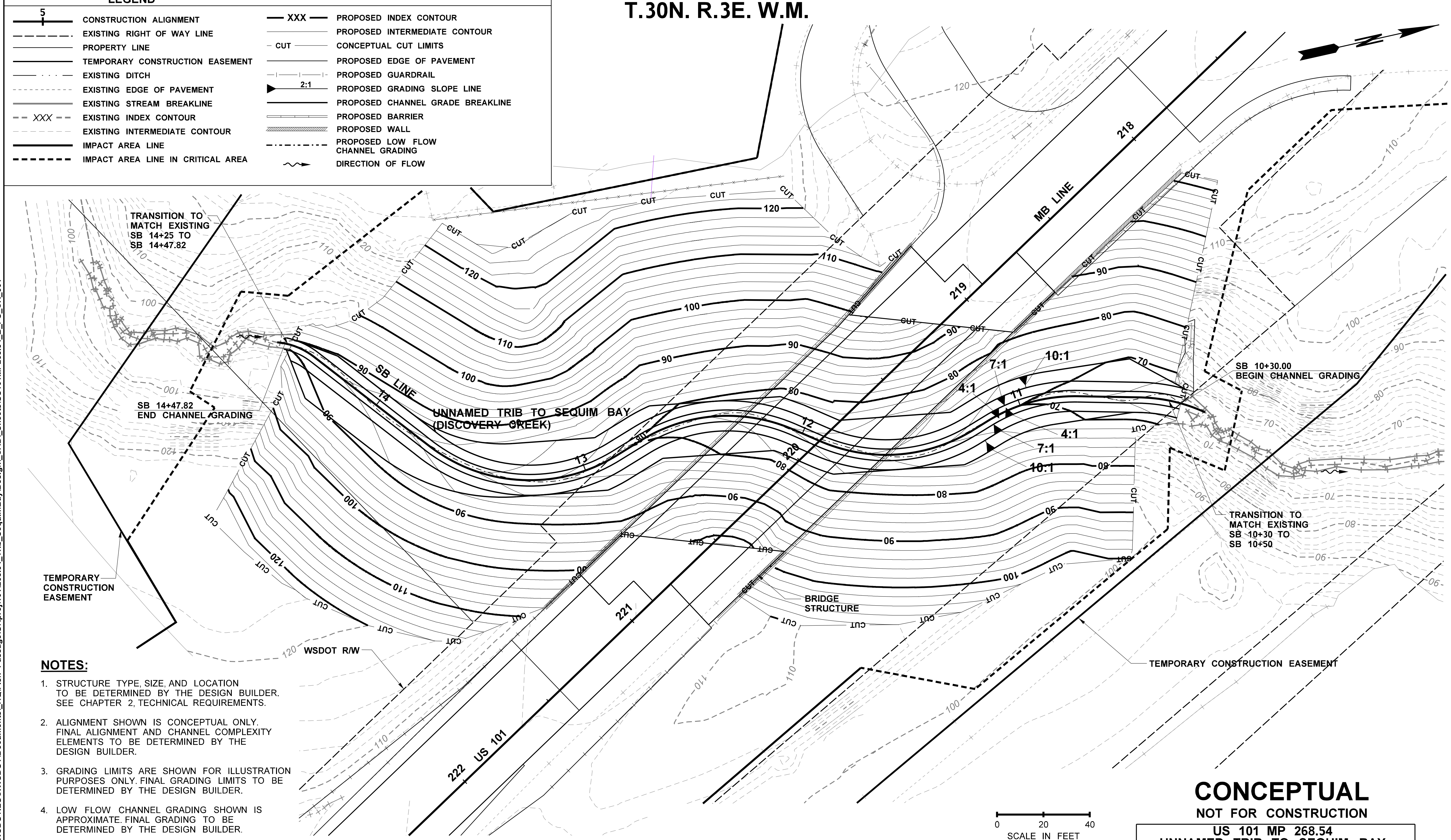
SHEET OF SHEETS

Appendix D: Stream Plan Sheets, Profile, Details

LEGEND

CONSTRUCTION ALIGNMENT	PROPOSED INDEX CONTOUR
EXISTING RIGHT OF WAY LINE	PROPOSED INTERMEDIATE CONTOUR
PROPERTY LINE	CONCEPTUAL CUT LIMITS
TEMPORARY CONSTRUCTION EASEMENT	PROPOSED EDGE OF PAVEMENT
EXISTING DITCH	PROPOSED GUARDRAIL
EXISTING EDGE OF PAVEMENT	PROPOSED GRADING SLOPE LINE
EXISTING STREAM BREAKLINE	PROPOSED CHANNEL GRADE BREAKLINE
EXISTING INDEX CONTOUR	PROPOSED BARRIER
EXISTING INTERMEDIATE CONTOUR	PROPOSED WALL
IMPACT AREA LINE	PROPOSED LOW FLOW CHANNEL GRADING
IMPACT AREA LINE IN CRITICAL AREA	DIRECTION OF FLOW

T.30N. R.3E. W.M.



NOTES:

1. STRUCTURE TYPE, SIZE, AND LOCATION TO BE DETERMINED BY THE DESIGN BUILDER. SEE CHAPTER 2, TECHNICAL REQUIREMENTS.
2. ALIGNMENT SHOWN IS CONCEPTUAL ONLY. FINAL ALIGNMENT AND CHANNEL COMPLEXITY ELEMENTS TO BE DETERMINED BY THE DESIGN BUILDER.
3. GRADING LIMITS ARE SHOWN FOR ILLUSTRATION PURPOSES ONLY. FINAL GRADING LIMITS TO BE DETERMINED BY THE DESIGN BUILDER.
4. LOW FLOW CHANNEL GRADING SHOWN IS APPROXIMATE. FINAL GRADING TO BE DETERMINED BY THE DESIGN BUILDER.

0 20 40
SCALE IN FEET

CONCEPTUAL
NOT FOR CONSTRUCTION

US 101 MP 268.54
UNNAMED TRIB TO SEQUIM BAY

pw:\\HQOLYMAPPW03P.WSDOT.LOC:WSDOT\Documents_HQ\Fish Passage\ORproj\101\268.54_Trib_SequimBay\Design_CAD_Sheets\US101MP268.54_B_PS_CR_001

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DESIGNED BY	C. DUBOW
ENTERED BY	J. TYLER
CHECKED BY	T. NABOURS
PROJ. ENGR.	B. ELLIOTT
REGIONAL ADM.	J. WYNANDS

REVISION | DATE | BY

REGION NO. 10 | STATE WASH | FED.AID PROJ.NO.
JOB NUMBER
CONTRACT NO. | LOCATION NO. XL6115

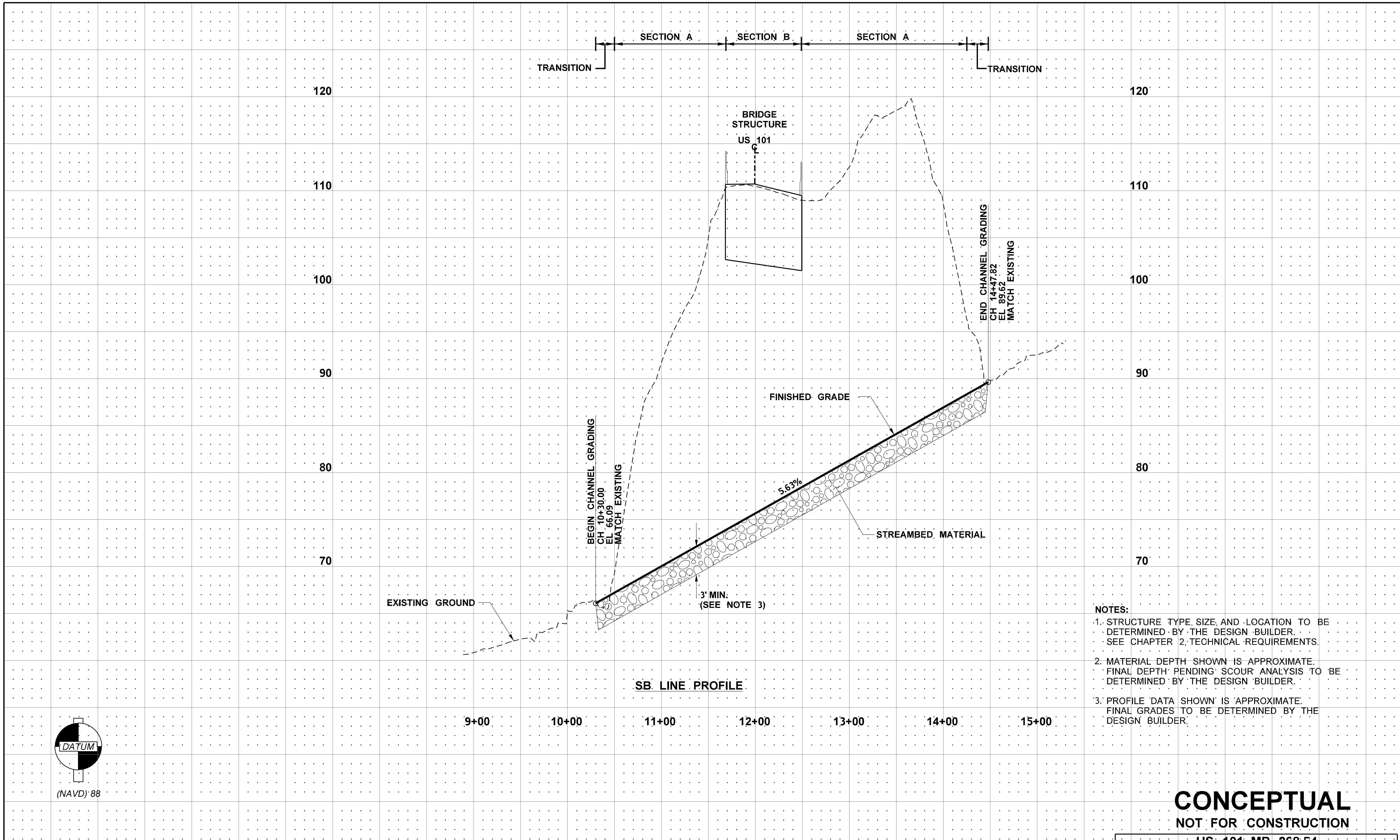
P.E. STAMP BOX DATE
P.E. STAMP BOX DATE

Washington State Department of Transportation
Parametrix

US 101/JEFFERSON/
CLALLAM COUNTY FISH BARRIERS -
REMOVE FISH BARRIERS

STREAM AND GRADING PLAN

PLAN REF NO CR1-B
SHEET OF SHEETS



SB LINE PROFILE

NOTES:

1. STRUCTURE TYPE, SIZE, AND LOCATION TO BE DETERMINED BY THE DESIGN BUILDER. SEE CHAPTER 2, TECHNICAL REQUIREMENTS.
2. MATERIAL DEPTH SHOWN IS APPROXIMATE. FINAL DEPTH PENDING SCOUR ANALYSIS TO BE DETERMINED BY THE DESIGN BUILDER.
3. PROFILE DATA SHOWN IS APPROXIMATE. FINAL GRADES TO BE DETERMINED BY THE DESIGN BUILDER.

CONCEPTUAL
NOT FOR CONSTRUCTION

US 101 MP 268.54
UNNAMED TRIB TO SEQUIM BAY

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ENTERED BY	J. TYLER			
CHECKED BY	T. NABOURS			
PROJ. ENGR.	B. ELLIOTT			
REGIONAL ADM.	J. WYNANDS	REVISION	DATE	BY

REGION NO.	STATE	FED.AID PROJ.NO.
10	WASH	
JOB NUMBER		
CONTRACT NO.	LOCATION NO. XL6115	

P.E. STAMP BOX DATE

P.E. STAMP BOX DATE

Washington State Department of Transportation

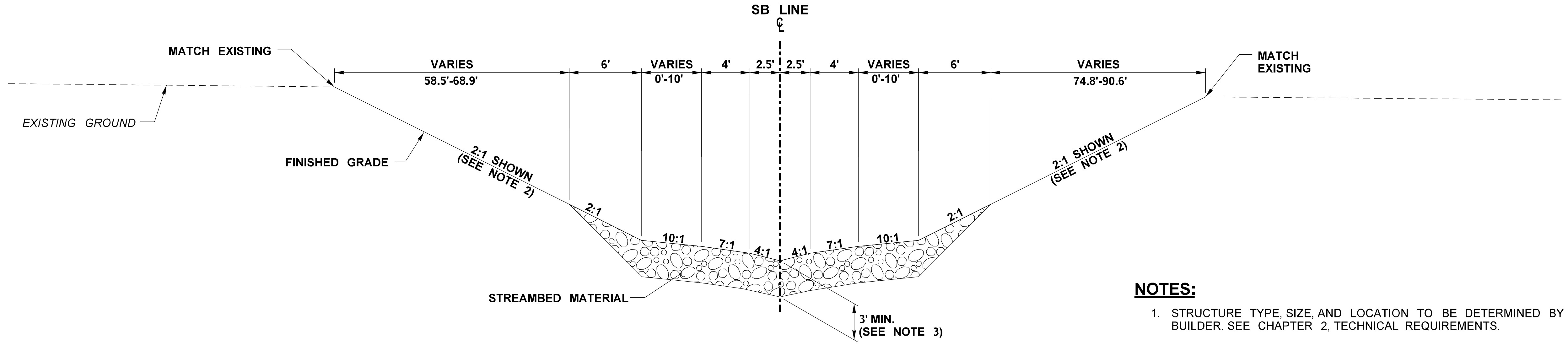
Parametrix

US 101/JEFFERSON/
CLALLAM COUNTY FISH BARRIERS -
REMOVE FISH BARRIERS

STREAM PROFILE

PLAN REF. NO. CP1-B

SHEET OF SHEETS

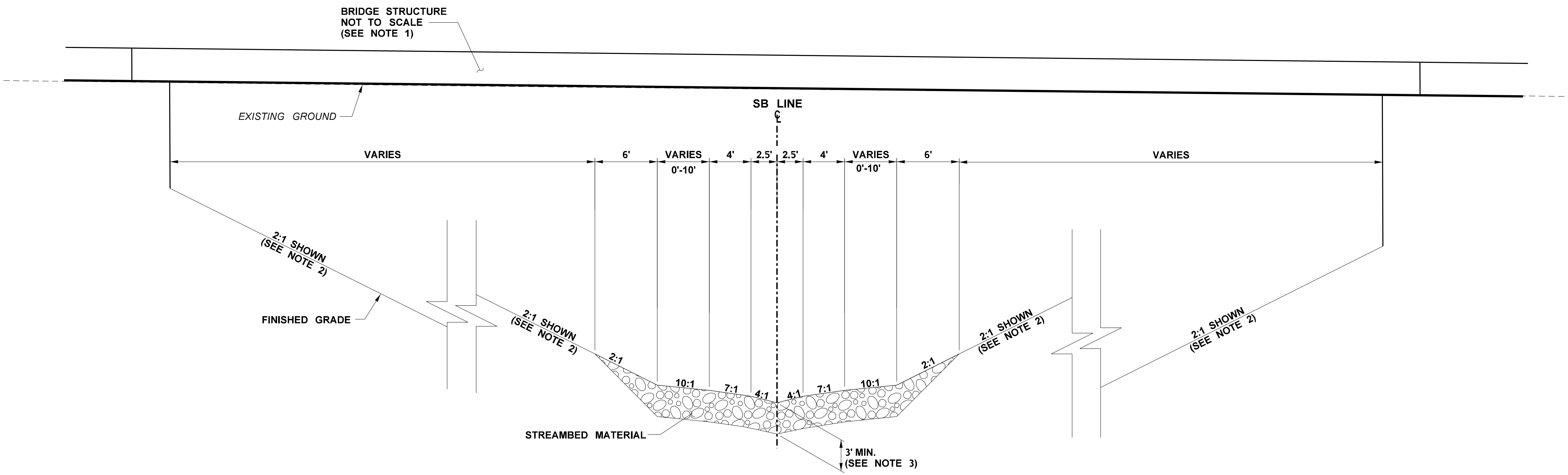


SECTION A

STATION
SB 10+50.00 TO SB 11+68.60
SB 12+48.86 TO SB 14+25

NOTES:

1. STRUCTURE TYPE, SIZE, AND LOCATION TO BE DETERMINED BY THE DESIGN BUILDER. SEE CHAPTER 2, TECHNICAL REQUIREMENTS.
2. GRADING LIMITS ARE SHOWN FOR ILLUSTRATION PURPOSES ONLY. FINAL GRADING LIMITS TO BE DETERMINED BY THE DESIGN BUILDER. SLOPE VARIES AT TRANSITIONS TO EXISTING.
3. MATERIAL DEPTH SHOWN IS APPROXIMATE. FINAL DEPTH PENDING SCOUR ANALYSIS, TO BE DETERMINED BY THE DESIGN BUILDER.



SECTION B

STATION
SB 11+68.60 TO SB 12+48.86

CONCEPTUAL

NOT FOR CONSTRUCTION

NOT TO SCALE

US 101 MP 268.54
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DESIGNED BY	C. DUBOW
ENTERED BY	J. TYLER
CHECKED BY	T. NABOURS
PROJ. ENGR.	B. ELLIOTT
REGIONAL ADM.	J. WYNANDS

REVISION | DATE | BY

REGION NO.	STATE	FED.AID PROJ.NO.
10	WASH	
JOB NUMBER		
CONTRACT NO.		LOCATION NO. XL6115

P.E. STAMP BOX DATE

P.E. STAMP BOX DATE

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US 101/JEFFERSON/
CLALLAM COUNTY FISH BARRIERS -
REMOVE FISH BARRIERS

STREAM DETAILS

PLAN REF NO CD1-B

SHEET OF SHEETS

pw:\\HQOLYMAPPPW03P.WSDOT.LOC:WSDOT\Documents_HQ\Fish Passage\ORproj\101\268.54_Trib_SequimBay\Design_CAD_Sheets\US101MP268.54_B_DE_CD_001